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Science & Technology

Third World

INDIA: DEPARTMENT OF SPACE ANNUAL REPORT 1988-89

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HIGHLIGHTS 1988-89

INDIAN REMOTE SENSING SATELLITE (IRS)

IRS-1A, the first of the series of indigenous state-of-art remote sensing satellites, was successfully launched into a polar sun-synchronous orbit on March 17, 1988 from the Soviet Cosmodrome at Baikonur. IRS-1A, weighing about 1,000 kg, carries two cameras, LISS-I and LISS-II with resolutions of 73 metres and 36.5 metres respectively for imaging over the Indian continent with a swath width of about 140 km during each pass over the country.

Since its launch and operationalisation, IRS-1A has been functioning satisfactorily. IRS-1A has already provided over 16,000 LISS-I imageries and 65,000 LISS-II imageries and has covered the entire country eleven times. The quality of the images is comparable with the best of the contemporary satellites. Expected turn-around times for the supply of data products have been fully realised on an operational basis.

The follow-on satellite, IRS-1B, which is identical to IRS-1A, is slated for launch in 1991 to provide continuity of remote sensing services as an integral part of the National Natural Resources Management System (NNRMS).

INSAT-I

INSAT-IB has satisfactorily completed over five and a half years of operational service in the areas of telecommunications, meteorology, TV and radio net-working. As many as 4,348 two-way voice or equivalent circuits are in operational use over 105 telecommunication routes through INSAT. 23,942 meteorological VHRR images were commanded during 1988. Over 250 TV and 100 radio stations are in the INSAT network. Additional fixed satellite service utilisation and in-orbit back-up capability have been provided with the launch of INSAT-IC on July 22, 1988.

Fabrication of INSAT-ID is proceeding on schedule. In view of the non-availability of a timely Space Shuttle launch, the launch of INSAT-ID was moved to a commercial Delta launch vehicle from USA.

The INSAT-I satellites are built by the Ford Aerospace Corporation of USA.

INSAT-II TS

INSAT-II satellites being indigenously fabricated will replace the INSAT-I series of satellites. Compared to the INSAT-I series, the INSAT-II satellites are heavier, more complex and can provide substantially higher quantum of telecom services to the nation. The INSAT-II system consists of two test satellites followed by three operational satellites. The first INSAT-II Test Spacecraft is expected to be ready for launch around mid-1990 with the second spacecraft following 12 months later.

During the year, fabrication and testing of most of the structural model components and sub-systems of INSAT-II TS were completed. Fabrication of the Electrical Thermal Model (ETM) hardware is in final stages.

The launch service agreement for the first two INSAT-II spacecraft on-board Ariane has been signed.

AUGMENTED SATELLITE LAUNCH VEHICLE (ASLV)

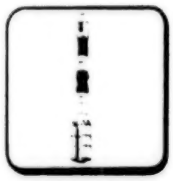
ASLV is designed to provide a low cost operational vehicle to launch 150 kg class satellites into low earth orbits, and also to validate many of the advanced technologies needed for the larger operational vehicles such as the PSLV.

The first development flight of ASLV resulted in an unsuccessful mission in March 1987 due to non-ignition of the first stage motor. The second ASLV flight was attempted on July 13, 1988 incorporating certain modifications in the ignition system, among other things, based on the failure analysis of D1 flight. The vehicle had a perfect lift-off and the performance of strap-on stage was nominal and the ignition of the first stage took place as stipulated. However, due to excessive loads built up subsequently, the mission was unsuccessful. While the specially constituted Failure Analysis Committee and an Expert Review Panel are finalising their report on the failure of the mission and their recommendations for modifications, the two ASLV flights have validated a large number of advanced technologies which will form important inputs for the PSLV.

STRETCHED ROHINI SATELLITE SERIES (SROSS)

The 150 kg SROSS-1 and SROSS-2 missions could not be fulfilled due to ASLV failures. SROSS-2 carried a joint remote sensing payload developed with the West German Aerospace Agency, DFVLR, in addition to a gamma ray astronomy payload. The future SROSS series is expected to carry out a number of scientific experiments in aeronomy provided by the National Physical

Laboratory (NPL) and the Physical Research Laboratory (PRL) and astronomy experiments developed by the Indian Space Research Organisation (ISRO) and the Tata Institute of Fundamental Research (TIFR).



POLAR SATELLITE LAUNCH VEHICLE (PSLV)

Considerable progress has been made in the development of PSLV launch vehicle which is designed for placing 1,000 kg class IRS type of remote sensing satellites into sun-synchronous, polar orbits at an altitude of around 1,000 km. Unlike its all solid-stage predecessors, the PSLV has a liquid propellant second stage and a liquid upper stage. A significant achievement is the total indigenisation of liquid propellant and the booster which are now being manufactured by the Indian industries through technology transfer from ISRO.

PSLV Project has entered qualification phase. Proto hardware of many sub-systems have been realised, functionally verified and qualification testing commenced. First stage motor segments have been fabricated, pressure tested and cast with propellant. The second stage 'Vikas' engine successfully underwent the 180 sec. endurance test. The third stage composite motor case, one of the largest of its kind in the world, has been qualified and cast with high energy propellant for static tests. The first-off assemblies of most of the light alloy structures have been realised. All the avionic systems are under various stages of test and evaluation.

The Mobile Service Tower has been erected to its full height of 75m. Precision tracking radar is in advanced stages of fabrication.

GEO-SYNCHRONOUS SATELLITE LAUNCH VEHICLE (GSLV)

The indigenous capability for the launch of INSAT-II class of spacecraft is planned to be achieved in the 1990s with the development of Geo-synchronous Launch Vehicle (GSLV). GSLV is being configured in such a way that the elements and infrastructure coming out of PSLV programme are maximally used. GSLV will, in the subsequent phase, incorporate a high energy cryogenic upper stage for enhanced performance. Initial efforts for the development of the cryogenic engines/stages for such an application, requiring long lead time, are underway.

During the current year, mission design, analysis and vehicle sizing for a large number of GSLV configurations using a variety of stage modules have been carried out and the options narrowed down for final selection. Under cryogenic technology development programme three versions of the regeneratively cooled sub-scale engines of 1,000 kg class were designed and fabrication initiated. Detailed design and engineering of the test facility for sub-scale engine was completed and facility elements ordered.

NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM (NNRMS)

The Department of Space is the nodal agency for the evolution and establishment of NNRMS. With the participation of Central and State agencies, the NNRMS undertook a number of resources survey and monitoring projects. A set of projects under NNRMS has been identified for implementation in mission mode. Remote Sensing Application Projects have been formulated, identifying selected application studies for large scale demonstration in collaboration with user agencies.

Successful launch and subsequent operationalisation of IRS-1A satellite has provided considerable impetus to application of Space-based remote sensing in the country. ISRO/DOS has taken several steps towards making available remote sensing data on a continued, assured and enhanced basis to the user agencies in the country. Five Regional Remote Sensing Service Centres (RRSSCs) and a number of Associate Centres have been set up around the country under NNRMS. As many as 12 States have established State Remote Sensing Application Centres. Several national level projects are being conducted on various resource themes with active collaboration of user community at Central and State level. Over 3,000 users have been trained in the remote sensing techniques.

MICROWAVE REMOTE SENSING PROGRAMME

Several systems studies relating to the Microwave Remote Sensing Programme were conducted during the year. A detailed system study for development of aircraft version of the synthetic aperture radar has been made. Demonstration surveys using sensors on-board aircraft were also carried out. A Side-Looking Air-borne Radar (SLAR) system has been developed and test flights were carried out.

MAJOR INDIAN SPACE MISSIONS 1985-95

MISSIONS	SEVENTH PLAN					EIGHTH PLAN					
	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
SROSS ASLV			D-1	D-2		D-3/C-1		D-4/C-2			
IRS				1-A PROCURED LAUNCH		EM	1-B PROCURED LAUNCH		1-C PROCURED LAUNCH OR PSLV D3/01		1-D/2-A
PSLV						D-1	SPACE SCIENCE S&R PIGGY BACK D-2		D-3/01		D-4/02
INSAT				PROCURED S/C 1-C PROCURED LAUNCH	PROCURED S/C 1-D PROCURED LAUNCH	INDIGENOUS S/C II-TS 1(A) PROCURED LAUNCH	INDIGENOUS S/C II-TS 2(B) PROCURED LAUNCH		INDIGENOUS S/C II (C) PROCURED LAUNC	INDIGENOUS S/C II (D) CURED LAUNCH	
GSLV										TMP/PIGGY BACK D-1	TMP/PIGGY BACK D-2

Introduction

November 21, 1988 marked the 25th anniversary of the Indian Space Programme. The Silver Jubilee year saw three major launch campaigns: orbiting of an operational remote sensing satellite IRS-1A, a development flight of the Augmented Satellite Launch Vehicle, ASLV-D2, and orbiting of an operational communications satellite, INSAT-IC. As is typical of development plans of such high technology areas, these efforts resulted in some significant successes and a few setbacks. The primary goal of the programme, however, remained the same, namely, self-reliant use of space technology for national development.

IRS-1A which was launched on March 17, 1988 by a Soviet 'Vostok' rocket, attained its designated orbital destination on April 7, 1988. Since then data from the two cameras on-board is collected on a routine basis as per the IRS referencing scheme. Placed in a sun-synchronous orbit, IRS-1A enables study of natural resources in various seasons under the same illumination conditions. In-flight calibration is carried out regularly to evaluate the systems performance. Until end of 1988 the satellite has provided over eleven cycles of coverage of the country. The two cameras on-board have acquired more than 75,000 images. Evaluation of the IRS-1A mission, based on its first six months of operations, has demonstrated the fulfilment of all the basic mission objectives. The quality of the images has been determined to be comparable with the best of contemporary satellites. Throughput capability and the turn-around times for generation of different levels of data products have been fully realised on an operational basis.

The second developmental flight of the Augmented Satellite Launch Vehicle, ASLV-D2, took place on July 13, 1988. The mission objective could not be accomplished due to abnormal performance of the vehicle about 46 seconds after lift-off. The launch complex and the ground station systems performed to specifications. Valuable data was acquired through telemetry, tracking and other aids which have been analysed in detail by the Failure Analysis Committee to determine the cause of the failure. An Experts Review Panel at the national level is also reviewing all aspects of the ASLV flights and will come out with suitable recommendations for subsequent flights of ASLV.

INSAT-IC was launched on July 22, 1988 on a European Ariane rocket. The satellite went through orbit raising and deployment operations in a flawless manner.

Soon after achieving the 'on-orbit' configuration, however, it experienced a setback resulting in the loss of about half of the payload/house-keeping equipment. In spite of this setback, with careful management of the satellite, considerable number of services from the INSAT-IC have been restored and efforts have been initiated to utilise the additional capacity available from INSAT-IC.

INSAT-IB, meanwhile, completed more than five years of satisfactory operational service. About 4,350 two-way voice or equivalent circuits are in operational use over 105 telecommunication routes through INSAT. As many as 250 TV and over 100 radio stations in the country are now in the INSAT network. Nearly 24,000 meteorological images have been obtained from the INSAT VHRR. A Standard Time and Frequency Signal dissemination service has also been commissioned using INSAT.

Fabrication of INSAT-ID is on schedule. Spacecraft level tests have commenced and the launch is scheduled for April/May 1989 on a Delta rocket.

The Polar Satellite Launch Vehicle (PSLV) project has entered the qualification phase. Qualification testing of sub-systems have commenced. Proof pressure testing of motor cases and propellant segment assemblies are being carried out. The second stage 'Vikas' engine underwent a 180 sec. endurance test successfully and a number of tests on the high performance fourth stage liquid engine were conducted. The third stage composite motor case, one of the largest of its kind in the world, has been

qualified and cast with high energy propellant for static tests. First-off assemblies of most of the light alloy structures such as interstages, heatshield, etc., have been realised. Avionics systems are in various stages of testing and qualification. The Mobile Service Tower has been erected to its full 75m height and the precision tracking radar development is nearing completion.

Substantial progress was achieved in the fabrication of the INSAT-II test spacecraft sub-system for the Structural Model (SM) and the Electrical Thermal Model (ETM). Both SM and ETM structures are nearing completion. Integration of the communication and VHRR packages are in an advanced stage. Positioning and installation of a number of sub-systems of the Large Space Simulation Chamber (LSSC) have been carried out. Launch agreement has been signed for the first two INSAT-II test spacecraft on Ariane rockets.

Under the National Natural Resources Management System (NNRMS) a number of resources survey and monitoring projects were undertaken by ISRO/DOS with the participation of Central and State agencies. Regional Remote Sensing Service Centres (RRSSCs) at Jodhpur, Nagpur and Kharagpur have been commissioned in addition to the Bangalore and Dehra Dun Centres. Remote sensing application studies in agriculture, water resources, environment and mineral resources have been energised in a project mode.

Production of developmental TV programmes in the areas of agriculture, health and animal husbandry continued. Programmes with special emphasis on drought, oil seed farming, water conservation, wasteland development and consumer education were made.

Development activities have begun in closely co-ordinated national and international programmes in the areas of Satellite-Aided Search and Rescue and the use of satellites for radio determination, navigation and mobile communication services.

A number of ISRO and NPSA developed technologies were transferred for commercial production under the Department's Technology Transfer Scheme.

Studies and advance work for future programmes such as Geo-synchronous Satellite Launch Vehicle, Microwave Remote Sensing, etc., have progressed.

Considering the progress made by the Indian Space Programme during the last 25 years, the International Astronautical Federation (IAF) held the 39th Astronautical Congress at Bangalore, India. All major space organisations around the world participated in this Congress.

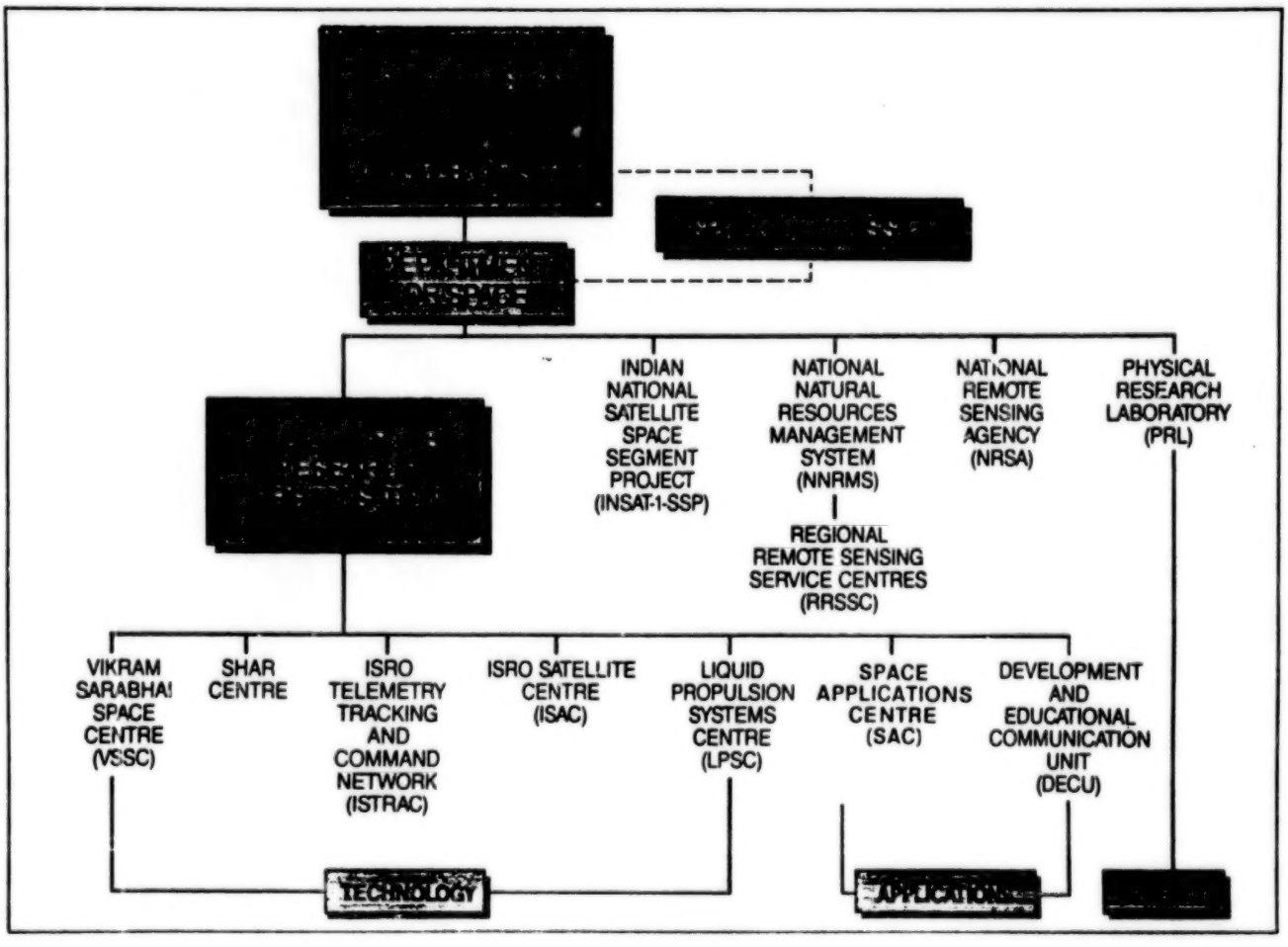
A national seminar on IRS-1A mission and its application potential was conducted during December 1988 at NRSA, Hyderabad. Emphasis was given to the presentation of case studies carried out using IRS-1A Data and its greater utilisation in future. Nearly 300 scientists and resource managers belonging to the Central and State government agencies, educational/research institutions and industries participated in this seminar. □

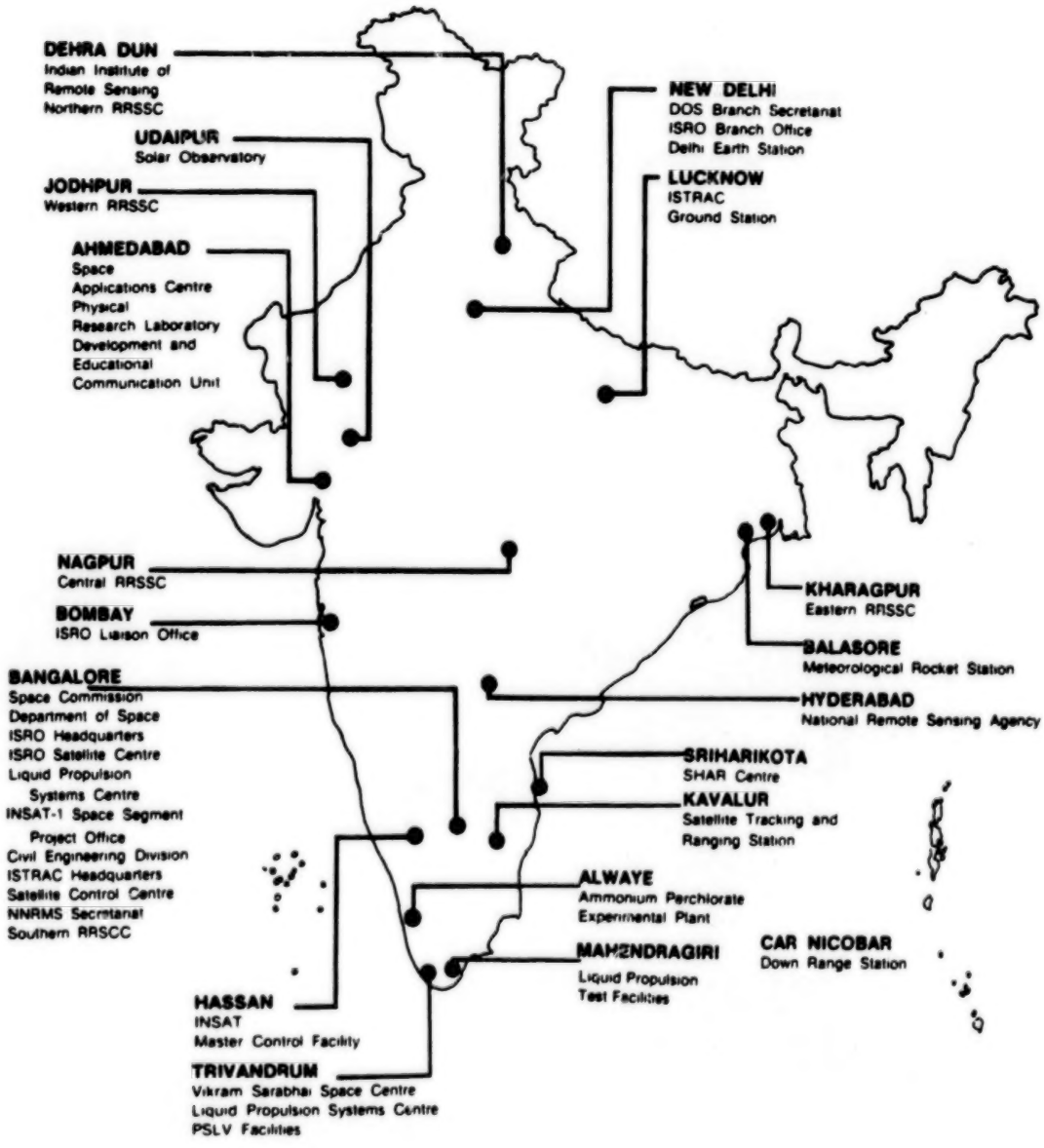
Organisation

In order to promote unified development and applications of space science and technology for national development, the Space Commission and the Department of Space were created in 1972. The policies framed by the Space Commission are implemented by the Department of Space (DOS) through the Indian Space Research Organisation (ISRO), the National Remote Sensing Agency (NRSA), the INSAT-I Space Segment Project Office and other agencies.

DOS is also the nodal department charged with the responsibility of establishing the National Natural Resources Management System (NNRMS) in association with the various Central and State agencies.

The development activities of ISRO are carried out by the following Centres/Units located around the country: Vikram Sarabhai Space Centre (VSSC) at Trivandrum; ISRO Satellite Centre (ISAC) at Bangalore; SHAR Centre at Sriharikota; Space Applications Centre (SAC) at Ahmedabad; Liquid Propulsion Systems Centre (LPSC) with its facilities at Bangalore, Trivandrum and Mahendragiri; ISRO Telemetry Tracking and Command Network (ISTRAC) with its network of ground stations; and the Development and Educational Communication Unit (DECU) at Ahmedabad. The ISRO Council and the ISRO Headquarters at Bangalore provide the overall guidance and direction to the scientific, technological and managerial tasks. Programme offices in specialised areas function as a part of the Central Management at ISRO HQ.





Space Centres and Units

RESPOND, the sponsored research scheme of ISRO, supports research activities at the academic and research institutions of the country in the areas of Space Science, Technology and Applications.

The Physical Research Laboratory (PRL) at Ahmedabad is an autonomous institution supported mainly by DOS and specialises in research programmes in space sciences. The Civil works, including specialised structures for the Space Programme, are executed by the centralised Civil Engineering Division (CED). □

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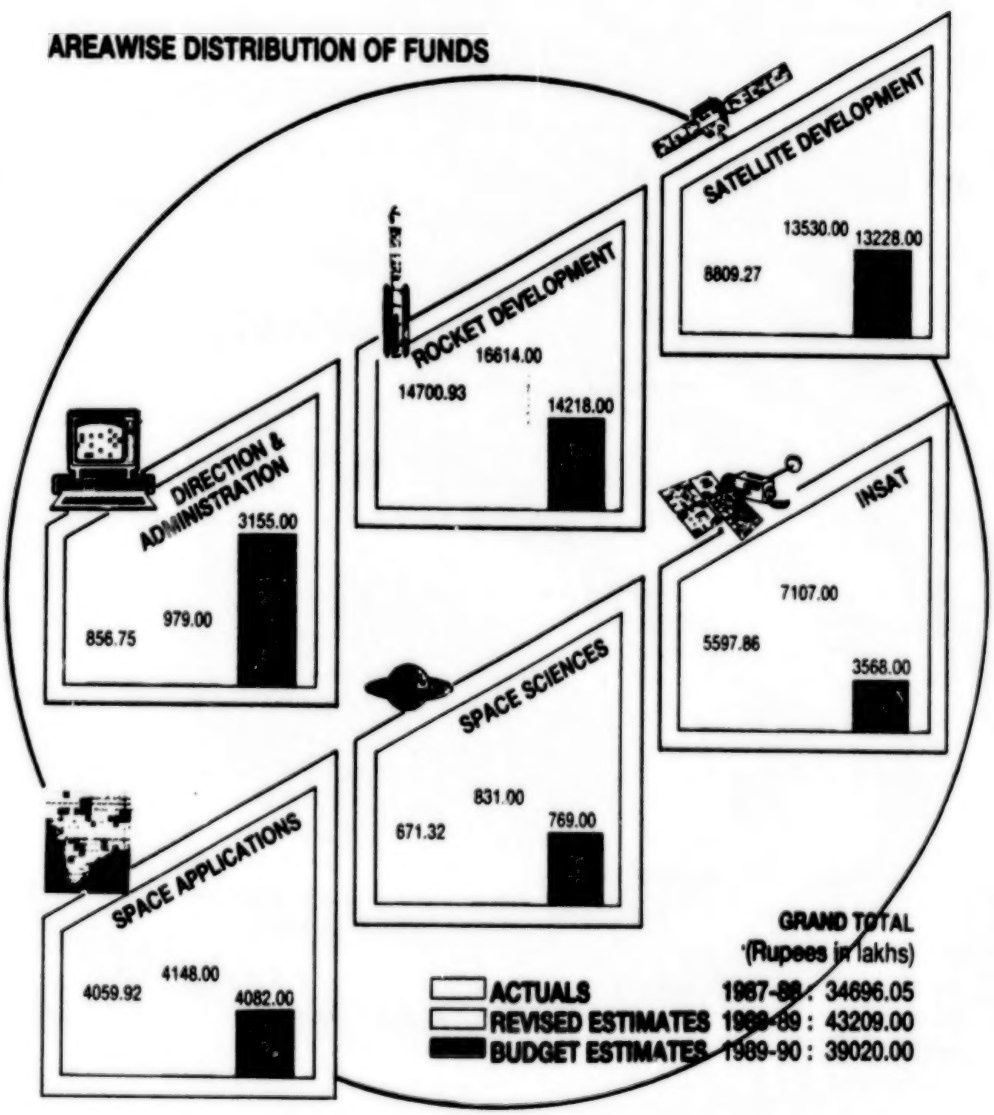


Space Applications

The Primary objective of the Indian Space Programme is to establish operational Space Services in a self-reliant manner. The main thrusts of the Programme are (i) satellite-based communications for various applications; (ii) satellite-based resources survey and management, and environmental monitoring; (iii) meteorological applications; and (iv) development and operationalisation of indigenous satellites, launch vehicles and associated ground segment for providing these space-based services. The indigenous development of application satellites, their payload and the capability to launch and operate these satellites are integral to these objectives.

THE INSAT SYSTEM

The first generation Indian National Satellite System (INSAT-I) represents India's first step towards implementing operational space systems for identified national requirements. INSAT-I is a multi-agency, multi-purpose operational satellite system for domestic telecommunications, meteorological observation and data relay, nationwide direct satellite TV broadcasting to augmented community TV receivers in rural and remote areas, and nation wide TV programme distribution for re-broadcasting through terrestrial transmitters.

The INSAT System is a joint venture of the Department of Space (DOS), the Department of Telecommunications (DOT), the India Meteorological Department (IMD), All India Radio (AIR) and Doordarshan. The overall co-ordination and management of the INSAT system rests with the high level inter-ministerial INSAT Co-ordination Committee (ICC). The Secretariat of this Committee resides in the Department of Space. The Department of Space has the direct responsibility for establishment and operation of the INSAT space-segment facilities.

The INSAT-I System was envisaged with a space-segment consisting of two multi-purpose satellites, one as the primary satellite providing all services and the other as a major path satellite providing certain additional Fixed Satellite Service (FSS) utilisation and also certain on-orbit back-up capability. The INSAT-I satellites are built by the Ford Aerospace Corporation of USA under contract with DOS. The INSAT-IB satellite, launched in August 1983 and now in its sixth year of operational service, is operating as the primary INSAT-I satellite from 74°E longitude.

The initial INSAT-I space segment configuration was completed in the third quarter of 1988 with the successful launch of INSAT-IC on July 22, 1988 and placement at 93.5°E longitude. However, due to a power bus anomaly on one of the two power buses, the usable capacity of INSAT-IC has become diminished. In spite of the above setback, efforts are being made to utilise the remaining capacity. The next satellite in the INSAT-I series, namely, INSAT-ID is intended to replace INSAT-IB which is nearing its end of life. The launch of INSAT-ID is scheduled for April/May, 1989. Each INSAT-I satellite provides the following capabilities over its individual seven-year in-orbit design life:

(1) Twelve national coverage telecommunications transponders of 36 MHz bandwidth, each operating in 5935-6425 MHz (earth-to-satellite) and 3710-4200 MHz (satellite-to-earth) frequency bands with 32 dBW (min) EOL eirp over the primary coverage area.

(2) Two high-power national coverage TV broadcast transponders operating in 5855-5935 MHz (earth-to-space) and 2555-2635 MHz (space-to-earth) frequency bands, each capable of handling one direct broadcast (community reception) TV channel and five low-level carriers for services like radio programme distribution, disaster warning, etc., with a 42 dBW (min) EOL eirp over the primary coverage area. These transponders also support the dissemination of certain disaster warning and standard time and frequency signals.

(3) A VHRR instrument for meteorological earth imaging with visible (0.55-0.75μm) and infrared (10.5-12.5μm) band channels with resolutions of 2.75 and 11 km respectively, with half-hourly full earth coverage and sector scan capability.

(4) A data relay transponder with global receive coverage with a 402.75 MHz earth-to-satellite link for relay of meteorological, hydrological and oceanographic data from unattended land and ocean-based automatic collection-cum-transmission platforms.

In the early '90s, the foreign procured and foreign launched INSAT-I spacecraft will be gradually replaced by indigenously developed second-generation (INSAT-II) spacecraft which will eventually be launched from India by the Indian Geo-synchronous Satellite Launch Vehicle (GSLV). The operational INSAT-II spacecraft are to be preceded by two INSAT-II Test Spacecraft (INSAT-II TS) to be launched in 1990 and 1991, to demonstrate and flight-test the indigenous design and engineering of the spacecraft before pressing them into operational service.

Except for any minor modifications in spacecraft design resulting from the INSAT-II Test Spacecraft flight and on-orbit experience, the INSAT-II Test Spacecraft are identical in configuration as well as in their service payload complement with the intended operational INSAT-II spacecraft.

Based on the requirements for satellite services for the 1990s projected by the participating user agencies, namely, the Department of Telecommunications, the India Meteorological Department, All India Radio and Doordarshan, the second-generation INSAT-II space-segment and the associated spacecraft configuration have been defined under the umbrella of the INSAT Co-ordination Committee. The initial all-up INSAT-II space-segment is to have three multi-purpose satellites, two of them co-located at the primary orbital position and one at the major-path orbital position. The two spacecraft at the primary orbital position are to be co-located and station-kept in such a manner that they appear as a single large-capacity spacecraft in terms of their total Fixed Satellite Service (FSS) capacities in conventional and upper extended C-band, by use of orthogonal polarisation. Though multi-purpose and somewhat similar in configuration to INSAT-I spacecraft, each INSAT-II spacecraft has a considerably larger FSS payload complement and a higher resolution meteorological imaging instrument (VHRR) than an INSAT-I spacecraft. A 406 MHz distress signal alert detection payload for Search and Rescue (S&R) purposes has also been included in each of the two INSAT-II satellites. While no operational dependence is planned on the first INSAT-II Test Spacecraft, it is expected that at least the second INSAT-II Test Spacecraft will see operational service and will play an important role in the transition from the INSAT-I to the operational INSAT-II space segment.

INSAT Utilisation

As of 31st January 1989, INSAT-IB located at 74°E longitude has completed 65 months in orbit and over 63 months of operational service. All four service payloads on-board INSAT-IB are 'ON' and, except for one of the twelve FSS C-band transponder channels, are in satisfactory operation and full use. The C-band FSS capacity has been supplemented by two C-band transponder channels leased on an Indian Ocean Region (IOR) INTELSAT satellite. INSAT-IC located at 93.5°E longitude has completed 7 months in orbit.

As of 1st January 1989, a total of 79 receive/transmit telecommunications terminals of various sizes and capabilities (excluding NICNET micro-terminals) were operating in the INSAT telecommunications network providing some 4,348 two-way speech circuits or equivalent over 105 routes. These comprise 54 fixed, 14 transportable and 11 in captive networks (ONGC, ITI, NFL, Master Earth Station of NICNET and Government). Use of satellite capacity on Madras-New Delhi route by 'The Hindu' newspaper for facsimile transmission of fully

INSAT-I SYSTEM UTILISATION

composed pages for printing of its Delhi edition has continued. Over 100 additional earth stations, including 50 Rural Telegraphy Networks (SBRTN) Pilot Project in the North-Eastern Region are under various stages of implementation in the DOT network. Some 32 additional telecommunications earth stations were also under implementation for eight different captive/business networks. In the National Informatics Centre Network (NICNET), at present over 100 micro-terminals are operating; the plan is to eventually have one NICNET micro-terminal in every district headquarters. During the year various networks involving upto some 250 new earth stations of various types were cleared for INSAT access.

As of 31st December 1988, the INSAT-IB satellite had been commanded to give 23,942 meteorological images—23,835 full earth-disc and 107 sector scans.

Now in its sixth year of satisfactory operation, the INSAT-IB VHRR is one of the very few geo-stationary VHRR instruments that have completed long term satisfactory space operation without exercise of any redundancy. The Meteorological Data Utilisation Centre (MDUC) of IMD processes, utilises and disseminates the INSAT-I meteorological images. 'Upper Winds', 'Sea Surface Temperature', and 'Precipitation Index' data products are regularly generated by MDUC/IMD. The 0600 hrs. GMT VHRR image derived 'winds' are regularly put on the Global Telecommunications System (GTS) of the World Meteorological Organisation (WMO). 0300 hrs. GMT full-disk IR pictures are being transmitted as radio facsimile broadcast everyday for reception in the neighbouring countries. The INSAT-IB VHRR imageries are regularly used on Doordarshan's daily night news coverages as well as by 'The Hindu' newspaper's daily weather reporting. At present, repetitive and synoptic weather systems observations over the Indian Ocean area from geo-stationary orbit are available only from the INSAT System.

The MDUC/IMD-processed INSAT-IB VHRR data is now available in near-real-time at some 20 Secondary Data Utilisation Centre (SDUC) locations

in various parts of the country. Two of these locations are provided with the processed data over a CxS direct satellite retransmission facility. With the commissioning of this direct satellite retransmission facility, which also uses INSAT-IB, it is now possible to provide SDUC-type data at any location in the country without regard to its distance from Delhi (MDUC/IMD) and availability of point-to-point terrestrial transmission circuits. An improved system that will transmit processed VHRR imagery, weather charts and weather data, all multiplexed on to one carrier, is also under implementation. Once implemented, this system will provide meteorological information not only to SDUCs but to any one interested in this data on a broadcast mode. Initial trials on this system were carried out. The necessary equipment was developed by SAC, Ahmedabad, and the technology transferred to NITEL, Bhopal. The production of equipment has commenced. After INSAT-II (TS) launch, it will be necessary to process meteorological data from both satellites simultaneously in view of the overlapping life spans of INSAT-I and INSAT-II. The present MDUC will not be able to process INSAT-II data because of differences in data formats, etc., and the large volume of data to be handled. A joint IMD/DOS task group had been constituted for a detailed definition of INSAT-II (TS)/INSAT-II VHRR data processing facility at MDUC/IMD, New Delhi. The implementation of the earth-station segment of this facility has been taken up at SAC, Ahmedabad, on a turn-key basis. This earth-station which will work in the extended C-band is expected to be completed in 2½ years.

All of the intended initial set of 100 Data Collection Platforms (DCPs) have been installed. DCP data is also processed, utilised and disseminated by MDUC/IMD. One of these INSAT DCPs is deployed at the Indian base station, Schiramacher Hills, Antarctica. The Central Water Commission (CWC) has deployed 14 DCPs in the Yamuna catchment area for flood forecasting purposes. DCPs on buoys are undergoing test operation from April 1988.

All of the intended initial set of 100 Disaster Warning System (DWS) receivers have been installed in selected cyclone-prone east coastal areas of Andhra Pradesh and Tamil Nadu and the DWS uplink from Madras has been available. These DWS receivers are selectively addressable. The first operational use of the INSAT Disaster Warning System was in 1987. The IMD is also planning deployment of additional units of receivers in other cyclone-prone coastal areas of the country.

The two high-power S-band transponder channels on-board INSAT-IB are utilised by Doordarshan for nationally networked TV programmes feed, for Delhi-originated TV programmes feed for a large number of low power TV transmitters operating in the national TV system, or transmitting UGC sponsored higher education enrichment TV programmes, for school ETV programme feed in selected States and for area-specific direct TV broadcast to augmented community TV receivers in selected rural areas. These S-band transponders are also supporting a six channel radio networking service, the cyclone disaster warning service, Standard Time and Frequency Signal dissemination (by the National Physical Laboratory) and a direct satellite retransmissions facility for processed INSAT meteorological (VHRR) images. In addition, a C-band transponder channel is providing regional feeds for Maharashtra and Andhra Pradesh in a 'half-transponder TV' mode. The remarkable expansion of TV coverage in the country that has taken place in the last two years or so would not have been possible without the availability of satellite TV feed capability. As of November 1988, all of the 272 TV stations operating in the country were in the INSAT-IB network.

Some 2,000 Direct Reception Sets (DRSs) were also installed in the various parts of the country with

funding by the Ministry of Information & Broadcasting (MI&B). In addition, some 4,000 DRSs are reportedly deployed through other programmes/ initiatives. MI&B plans to deploy another 1,100 DRSs in the North-Eastern region out of which 75 DRSs have been supplied by KELTRON and are operating satisfactorily. During December 1988, the monthly use of the two S-band transponder channels and one C-band transponder channel has registered over 1,000 hrs. per month. From August 1988, a regional service for Tamil Nadu is being provided through the CxS transponder of INSAT-IB. During 1987-88, MI&B/Doordarshan have added two captive transportable TV uplink terminals. Thus, in addition to the two channel TV uplinking capability available from Delhi, there are now four transportable TV uplinking facilities available/ operating in the INSAT TV network.

The Radio Networking Service via INSAT is designed to provide reliable, high-fidelity, five-channel national/regional feeds for retransmission by AIR stations. At present all the intended centres of AIR numbering over 100 are equipped with five-channel S-band receive terminals and are in the INSAT Radio Network. In addition to a five-channel Radio Networking (RN) uplink capability available from Delhi, single channel uplinking capabilities are also available from Calcutta, Bombay and Madras. AIR has also taken action to add certain captive transportable RN uplinking terminals. The cumulative monthly utilisation of the five RN channels is now registering about 2,400 hrs. per month. A sixth radio networking channel for programme feed to the national service channel radio transmitter at Nagpur has also been operational for over a year now. This channel will support programme feeds to other radio transmitters as and when they get introduced in the national service channel network; this channel will also be used later for synchronisation of transmitters in the national channel network. A scheme for a regional radio service to Lakshadweep group of Islands using INSAT-based programme feed from Kavaratti is under finalisation. The satellite signal will also be used for tele-operation of this Very Low Power Radio Transmitter (VLPRT) network.

A Standard Time and Frequency Signal Dissemination Service (STFSDS), using a radio networking (RN) like CxS carrier on INSAT-IB, has been commissioned by the National Physical Laboratory (NPL). This service is available round the clock in a broadcast mode at downlink frequency in S-band and is receivable on a set-up consisting of an 8 ft diameter chicken mesh antenna, a front-end converter, an FM demodulator and a microprocessor-controlled signal decoder.

The Press Trust of India (PTI) Satellite News and Facsimile dissemination project uses a Radio Networking (RN) type channel on one of the broadcast (CxS) transponders of INSAT-IB to provide its news and information services at higher speed and increased volume directly to a wider range of users across the country. This project has been operationalised since mid '88.

The INSAT Systems Group (ISG) which is a part of Systems and Application Engineering Group (S&AEG) of Space Applications Centre has carried out several studies for enhancing the INSAT System Planning and Utilisation. Development of Satellite News Gathering (SNG) Service in CxS band and CxC band using ultraportable vehicle mounted terminals for TV/Radio was initiated.

INSAT-IC

INSAT-IC was launched on July 22, 1988 on Ariane flight 24. After its successful orbit raising operations and deployments, the satellite was placed in its "on-orbit" configuration on July 27, 1988. On July 29, 1988 the spacecraft experienced a 'loss of earth lock' because of a suspected grounding in one of the buses resulting in loss of about half of the payloads/house-keeping equipment. In view of the above losses, the thermal and power management of the satellite have become difficult. In spite of the above setbacks, efforts are being made to utilise the remaining capacity.

INSAT-ID

The INSAT-ID satellite, the fabrication of which commenced in October 1985, has made good progress. All the major sub-system level testings have been completed and the spacecraft-level tests have commenced. The INSAT-ID delivery is now expected in the first quarter of 1989 against the scheduled deadline of December 1988. Though basically identical in configuration to other INSAT-I satellites, the INSAT-ID has certain improved features in terms of a larger battery capacity to support a larger payload operation during eclipse periods, a 3:2 redundancy in output devices for CxC transponder channel Nos. 11 and 12, a larger propellant tank to permit additional propellant loading, etc.

Prior to the 'Challenger' accident, INSAT-ID was to have been launched by STS during October 1988—September 1989 period. In view of the non-availability of a timely STS launching in mid-1987, the launch of INSAT-ID was moved to a

NOT REPRODUCED

commercial Delta 4925 launch vehicle of McDonnel Douglas Corporation (MDC) of USA. The Delta 4925 launch of INSAT-ID is scheduled for April/May, 1989.

INSAT-II Test Spacecraft

The INSAT-II Test Spacecraft mission is aimed at designing, developing, testing and qualifying on ground, and operating and testing in space of two identical INSAT-II spacecraft of the defined INSAT-II space-segment during the 1990s.

INSAT-II Satellites will have enhanced capabilities and hence will be about 50% heavier than INSAT-I. INSAT-II will weigh about 1,900 kg at lift-off and about 860 kg in geo-synchronous orbit. The satellite has a length of about 23m in the fully deployed condition and has the capability to generate minimum End of Life (EOL) power of 1,180 watts. INSAT-II, like INSAT-I, is a three-axis-stabilised satellite with similar structure except for some modifications. The solar array consists of three full panels and two half panels and arranged in such a way to avoid partial deployments during transfer orbit phase. Apart from having two 1.77m deployable communication antennae on East and West faces of the satellites for providing C-band and S-band transmit function, INSAT-II has a third fixed antenna of 0.9m diameter added for all 6 GHz receive and VHRR and DRT and SAS & R data transmit functions resulting in greater mission function savings in case of deployment anomalies. For improved coverage for TT & C during on-orbit phase, a global horn is provided apart fror. the TT & C omni antenna. Each INSAT-II satellite will have a total of 18 FSS transponders, 12 in normal C-band and 6 in extended C-band with a capability to provide 32 dBW Edge of Coverage (EOC) eirp from 16 transponders for providing communication and television distribution services and 34 dBW from 2 high-power transponders to cater to specialised telecommunication requirements using roof top terminals. For Broadcast Satellite Service (BSS), each INSAT-II will use 2 high-power (42 dBW-eirp) S-band transponders. For the meteorological applications, INSAT-II will have a VHRR with improved resolution compared to INSAT-I viz., 2 km in the visible and 8 km in the infrared band channels. It will also have a Data Relay Transponder (DRT) with global receive coverage in UHF band for receiving meteorological, hydrological and oceanic data from unattended land and ocean based platforms and transmit them to a central facility. DRT also caters to the payload for satellite-aided search and rescue mission which is a new addition to INSAT system. This payload will provide for an instantaneous emergency alert capability in this part of the world and will form part of the international COSPAS-SARSAT system.

The INSAT-II TS project, sanctioned and formally started in April 1985, covers delivery of two spaceworthy INSAT-II Test Spacecraft along with required spares. The project also covers necessary augmentation of the INSAT Master Control Facility (MCF) at Hassan to simultaneously handle two INSAT-I and two INSAT-II (TS) Spacecraft, with one of the two INSAT-II (TS) spacecraft being in the orbit-raising phase. The programme elements of the

Project also cover establishment of the necessary infrastructure, around the existing facilities of DOS/ISRO, required for building and qualifying INSAT-II (TS) spacecraft and consequently also for supply to the INSAT System of the operational INSAT-II spacecraft that are to follow. One of the major new facilities being established in this connection at the ISRO Satellite Centre, Bangalore, is the Large Space Simulation Chamber (LSSC).

The first INSAT-II Test Spacecraft readiness/ availability for launch is expected around mid-1990 and that of the second spacecraft 12 months later. The launches are contemplated in the last quarters of 1990 and 1991 respectively.

Launch services agreements have been signed with Arianespace for the launch of first INSAT-II Test Spacecraft between October 1, 1990 and November 30, 1990 and Second INSAT-II Test Spacecraft between October 1, 1991 and November 30, 1991.

Structural Model (SM)/Electrical Thermal Model (ETM) sub-system fabrication is progressing satisfactorily and is in an advanced stage of development. The first spacecraft structure (SM) is under final assembly at HAL and it is expected to be delivered by HAL in early 1989.

PCBs for the ETM platform electronics have been fabricated and wiring and testing are in advanced stages.

Structural dummies of the communication payload sub-systems have been fabricated. Test and evaluation of various communication payload sub-systems for ETM are progressing satisfactorily and assembly of the packages on the south equipment panel has commenced. Tests on CxC feed have been conducted along with the reflector in the near field antenna test facility at SAC, preparatory to commencing range tests. Measurements on CxS feed along with first CFRP reflector has been completed.

Technical and commercial negotiations for the procurement of microprocessors for AOCE have also been completed and contract for this is under finalisation. The DUA (application use of Ariane) has been submitted and follow-up launch interface meeting has been held with ARIANESPACE during

October 1988 to review the DUA and actions on both sides have been noted for follow-up.

INSAT Master Control Facility (MCF)

The performance of the INSAT MCF systems has continued to be satisfactory; MCF availability for INSAT-IB & IC TT&C functions has been 100%. MCF has been augmented with a 7.5m diameter antenna and associated earth station equipment, a new stand alone telemetry and telecommand console for on-orbit control of INSAT-IB and also a back-up command generator. This new limited steerability 7.5m diameter antenna and the stand alone T&C console was able to handle on-orbit control of INSAT-IB during INSAT-IC launch/orbit-raising phase, and freed the two 14m diameter antenna and the main Satellite Control Centre (SCC) T&C consoles for launch phase/orbit-raising operations of INSAT-IC.

INSAT MCF is under augmentation for INSAT-II. The augmentation includes one new 11m diameter limited steerable antenna with associated earth station equipment, INSAT-II Satellite Control Centre (SCC) with associated computer facilities, associated civil works, etc. The INSAT-II related Civil Works at INSAT MCF are nearing completion. The contract for the 11m diameter antenna, all C-band equipment, tracking receiver, etc. have been awarded on a turn-key basis. The equipment in the extended C-band are being supplied by SAC/ISRO.

One of the above mentioned two new 11m diameter antennae for INSAT-II Programme (one with limited steerability) has been planned to be installed at MCF well before the INSAT-ID launch to ensure that in the nominal situation of INSAT-ID launch occurring while INSAT-IB as well as INSAT-IC are operational, the two 14m diameter fully steerable antennae are available to support INSAT-ID launch phase operations.

SATELLITE-AIDED SEARCH AND RESCUE PROGRAMME

The Satellite-Aided Search and Rescue Programme is overseen by an Inter-Agency Steering Committee. The activities under the Satellite-Aided Search and Rescue Programme have made substantial progress during the last two years, with the signing of the agreement with COSPAS-SARSAT Parties for the

use of the systems and operation of Local User Terminal(s) (LUT) in India. In the light of the changed structure of the earlier COSPAS-SARSAT organisation—from an inter-agency programme to an inter-governmental programme, the COSPAS-SARSAT Council has replaced the COSPAS-SARSAT Steering Committee, and India would be shortly taking decision on signing the Letter of Notification, as required by the new procedures, as a Ground Station Provider.

The contract for the procurement of LUT/Mission Control Centre (MCC) has been established and fabrication of antenna for the second LUT has been taken up at SHAR Centre. The 406 MHz payload on-board INSAT-II TS has been developed and the engineering model is nearing completion. The work on the Receive Terminal for INSAT-II down-link has also been taken up at SAC. The 406 MHz beacon development is progressing well and is expected to be ready by the end of this year (F/Y).

The first LUT and MCC are being located at ISTRAC, Bangalore. The civil works have been taken up and other infrastructural requirements are being taken care of. In accordance with the decision that the COSPAS-SARSAT ground system would be fully funded by the participating agencies, viz., Services, Shipping, Civil Aviation and Coast Guard, the arrangements are being worked out. In anticipation of the approval to be received from these agencies, the award of contract for the first system has been done.

India has been taking part in the COSPAS-SARSAT Operations/Technical Working Groups and Exercise Coordinating Committee Meetings called by the COSPAS-SARSAT Secretariat and ensuring that the Indian inputs are reflected properly in the procedures under evolution.

In the international co-operation front, the compatibility testing of the existing 243 MHz beacons has been taken up with NASA GSFC and the test beacons have been despatched for the tests scheduled from December 1988. NASA's inputs for the 406 MHz geo-stationary satellite experiment are being sought. Based on the discussions with Glavkosmos, the USSR team visited India in January 1989 with some 406 MHz beacons which were deployed in mountainous and high-sea conditions to evaluate the system performance in adverse conditions. Some of the existing 121.5 MHz beacons were deployed in the north to check their compatibility with COSPAS-SARSAT system and the limit of visibility from USSR's Novosibirsk LUT during December 6-8, 1988 and the results are under evaluation.

RADIO DETERMINATION, NAVIGATION AND MOBILE SATELLITE COMMUNICATION SERVICES

ISRO is planning an aeronautical satellite communication demonstration using INMARSAT space segment in the early 1990s. The participating agencies include Videsh Sanchar Nigam Limited (VSNL), Department of Telecommunications (DOT), National Airports Authority (NAA), Directorate General of Civil Aviation (DGCA) besides DOS. This is a new field of service being conceived for the purpose of providing data and voice communication between aircraft and ground. For this demonstration INMARSAT is providing one set of Aeronautical Earth Station (AES) avionics, an associated high gain aircraft antenna system and one set of AES functional test equipment.

ISRO has undertaken development of the INMARSAT Standard-C terminal and is involving many electronics industries from the design stage itself so that the terminals could be productionised early after technology transfer. The primary communication function of the Standard-C terminal

is text and data transmission to and from ships/remote location and terrestrial subscribers via a variety of public network. The Standard-C terminal development is in an advanced stage and is expected to be completed by end of 1989.

Under the Inter-Agency Steering Committee (IASC) on Radio Determination Satellite Service (RDSS) and Mobile Satellite Service (MSS) a Task Team was constituted to lay down specifications and standards for development of GPS receiver in India. ISRO has taken up the development of a sequential Global Positioning System (GPS) receiver capable of receiving the Coarse Acquisition (C/A) code from the US GPS satellites meant for satellite-aided navigation globally.

FREQUENCY MANAGEMENT

Frequency Management involves projecting the DOS/ISRO orbit-frequency requirements to the national and international level agencies responsible for frequency allocation and carrying out suitable co-ordination activities in close co-ordination with ISRO Centres and Units to protect operations of DOS/ISRO projects/programmes from intersystem interference point of view. This responsibility lies with the Frequency Management Office (FMO) in ISRO HQ. The frequency management activities include participation in the meetings of International Telecommunication Union (ITU)/CCIR Study Groups and other international fora like Space Frequency Co-ordination Group (SFCG) and providing technical contributions in Frequency Management area.

INDIAN REMOTE SENSING SATELLITE (IRS)

One of the major elements of the Indian Space Programme is the development and deployment of remote sensing spacecraft and the technology to use them towards the establishment of National Natural Resources Management System (NNRMS). Department of Space, being the nodal agency to establish NNRMS in the country, has been progressing various activities towards ensuring satellite data to the users and development of appropriate methodologies to utilise the data. Bhaskara I and II provided demonstrative experiments towards the development of an indigenous Indian Remote Sensing Satellite. A number of joint experiments carried out with multiple users helped in bringing out the potential of the technology and in planning sensors for the indigenous satellite system. A wide range of ground-based systems for reception processing and dissemination and utilisation of data were also established in the process. A series of IRS satellites is planned to provide continuity of operational use of remote sensing for natural resources management by ensuring supply of satellite data on a regular basis. IRS-1A satellite is the first in the series and it marks the transition from experimental applications of remote sensing technology to fully operational domestic systems. The data from IRS and other contemporary satellites will ultimately feed into the National Natural Resources Management System (NNRMS) where such data will be used by user agencies to meet the information needs of complex decision making

process in various natural resources sectors such as agriculture, water resources, forestry and ecology, geology, water sheds, marine fisheries and coastal management.

IRS-1A, weighing 975 kg was successfully launched on March 17, 1988, into a polar sun-synchronous orbit of 904 km by the Soviet launcher 'VOSTOK' from a cosmodrome at Baikonur in the Kazhakstan Republic of USSR.

After the injection of the spacecraft into earth orbit, the solar panel deployment, sun acquisition/earth acquisition and the three-axis stabilisation tasks as well as the S-band data link tests were carried out on the first day itself. The LISS-I payload was operated successfully on March 18, 1988. The X-band data link was tested on March 27, 1988 and LISS-II A & B Cameras were operated on March 28, 1988. IRS-1A attained its designated orbital destination on April 7, 1988. Since then the data is being collected on a routine basis as per the IRS referencing scheme and data products are being supplied to the users on an operational basis. As of December 1988 nearly 1,500 LISS-I data products and about 2,700 LISS-II data products have been supplied by the NRSA Data Centre.

IRS-1A enables the study of natural resources in various seasons under the same illumination conditions. The satellite returns to its original orbital trace after every 22 days, thus enabling repeated collection of data at the same place at the same local time. The orbit of IRS-1A is controlled so that the ground track at the equator will be within 148 km across the track from the nominal value. In order to facilitate convenient and unique identification of any of the geographical regions of interest and cataloguing of data products, an image referencing scheme designated by path and row numbers has been evolved for the Indian sub-continent.

IRS-1A has two types of imaging sensors, one with a spatial resolution of 72.5 metres and designated as LISS-I and the other with two separate imaging sensors designated as LISS-IIA and LISS-IIB with a spatial resolution of 36.25 metres each. LISS-I provides a swath of 148 km, while a composite swath of 145 km is attained by the two LISS-II sensors by suitable mounting of detectors in the focal plane of the system. The inflight calibration exercise is done on a regular basis to evaluate the system performance. The Spacecraft Control Centre located at Bangalore is the focal point for spacecraft health control and analysis, planning of all spacecraft operations and carrying out tracking network co-ordination. The data reception station at Shadnagar has the capability to receive the data from the satellite in both S and X-bands. It has a provision for Quick-Look display of one selected spectral band data of any of the selected imaging sensors. The data received from the imaging sensors are recorded on High Density Digital Tapes (HDDT).

The data reception station also provides facilities for carrying out calibration data analysis and cloud cover estimates. Besides these, attitude and orbit related elements of the satellite are computed with respect to paths and rows of image scenes acquired at the station and are suitably formatted in Ancillary Computer Compatible Tapes (ACCT). These tapes are used for further higher level processing of imageries data.

The successful accomplishments of IRS-1A mission involve the spacecraft platform, the imaging system, spacecraft control, data acquisition, processing and dissemination facilities. These provide the base on which further expansion and upgradation of services are planned.

With IRS-1A becoming the backbone of the National Natural Resources Management System providing vital inputs to the management of nation's resources, the continued availability of space imageries becomes one of the major requirements.

Based on the nominal life time estimate of 2½ to 3 years for IRS-1A, the launch of IRS-1B is planned in 1990-91 to provide continuity of services. IRS-1B, which is identical to IRS-1A in all respects, will provide continuity of services on an operational basis till 1993-94.

Considering the technology development scenario and user requirements during 1990's it has been decided to go in for a series of second generation remote sensing satellites after IRS-1B. Increased use of space imageries for different applications and requirement of higher resolution imageries for specific applications are the primary factors for going for the second generation IRS satellite from 1B onwards. In addition, the second generation IRS series will also have more frequent revisit capabilities, stereo viewing and on-board data recording. The second generation IRS satellites namely IRS-1C and 1D are being designed to incorporate sensors with spatial resolution of 20 metres in the multispectral bands and better than 10 metres in the panchromatic band, apart from stereo viewing, revisit and on-board data recording capabilities.

The spacecraft platform for IRS-1C/1D will be built around established design and the technology accrued from IRS-1A. However, the platform will have increased capability in terms of larger power generation and precision attitude control systems to meet the second generation imaging system requirement. The spacecraft attitude control system will be upgraded for even better platform stabilities in the 3-axis body stabilised configuration using inertial sensors, namely, 3-axis gyro system with updation from star sensor reference system.

NATIONAL NATURAL RESOURCES MANAGEMENT SYSTEM (NNRMS)

DOS as the nodal agency, has the total responsibility for the evolution and establishment of NNRMS in all Central Ministries/Agencies and State/Union Territory Governments concerned. Data from LANDSAT and SPOT missions were used to exploit the potential of remote sensing data for national natural resources survey and management. A wide range of ground based systems for reception, processing, dissemination and utilisation of data were also established in the process. The successful launch of IRS-1A and operationalisation of systems for the reception, processing and dissemination of its data have been the corner stone of ISRO's achievements in the area of remote sensing. The take-off of such a full fledged operational programme, which only a few nations could achieve around the globe, is now well poised to reach greater heights, through the series of satellites planned to be launched following IRS-1A for continuing the services and further improving upon its capabilities. There have been great deal of indigenous developments both in the space and ground segments of the IRS missions that provide wide ranging opportunities for the growth of remote sensing applications.

The initiatives taken over the years in terms of (i) development of space and ground segments, (ii) productionisation of a wide range of user oriented equipment in Indian industries, (iii) the development of application techniques and software, (iv) conduct of applications projects with user ministries and agencies, (v) establishment of infrastructure for training and servicing the users, Regional Remote Sensing Service Centres (RRSSCs) and above all, evolving an effective and innovative application oriented management system through National Natural Resources Management System (NNRMS) represent a unique opportunity for the country that needs to be exploited to its fullest potential.

Major components of NNRMS are (i) application studies as building blocks for generation of data base for Natural Resources Information System

(NRIS), (ii) establishment of infrastructure and generation of trained manpower, (iii) ensuring the supply of remote sensing data and facilitating its integration with the conventional system through appropriate collaborative application studies as stated at (i) above, (iv) technology developed with respect to hardware and software for processing of satellite and other data and (v) finally demonstrating operational NRIS at various levels, namely, district, state and country for resource management decision. This needs co-ordination with a large number of user departments/organisations both at Central and State levels. Department of Space has taken several steps during the current year to progress matters relating to remote sensing technology applications at the Central and State levels. These included setting up of appropriate facilities, development and transfer of methodologies in different application themes, development of low cost equipment for interpretation and processing of remote sensing data, trained manpower development, etc. Important application studies and efforts in other areas are briefly described in the following paragraphs.

IRS Utilisation Programme (IRS-UP) and Remote Sensing Applications Mission (RSAM)

Projects carried out under the IRS-UP with the participation of national and State level user agencies have resulted in the development of several operational packages towards application of remote sensing for various natural resources themes. These projects have helped in preparing the users towards greater utilisation of IRS-1A data which have now become available regularly.

Some of the application areas which showed high visibility and encouraging results during the IRS-UP have been selected to be carried out in mission mode under the Remote Sensing Application Mission (RSAM) Project. The project includes ground water potential zone mapping, large area crop acreage, urban sprawl, landuse mapping, saline/alkaline soil mapping, flood mapping and geological mapping. The RSAM projects have helped in operationalising remote sensing application for several resource themes. Most gratifying is the fact that the RSAM projects have found wide acceptance among the users as can be seen from their involvement and funding of the projects. For example, the wasteland mapping of 146 districts of India was completed in just over one year period with the active involvement of 20 user departments/agencies at State/Central levels and was fully funded by NWDB. The wasteland maps of all the selected 146 districts have been finalised and have been distributed to the nodal officers in the states for further dissemination to users. Similarly the application of remote sensing for ground water potential zone mapping has found an important place in the National Mission on Drinking Water Technology being co-ordinated by the Department of Rural Development. Under this, 57 mini-mission districts have been selected for detailed ground water potential zone mapping through remote sensing methods. It is planned to cover the entire country during the mission period.

The Department of Agriculture and Co-operation and the Department of Space have jointly launched

a major project on Remote Sensing Application Mission for agricultural applications as a Central Sector (Planning) scheme funded by Department of Agriculture and Co-operation. This project has mainly six sub-projects dealing with large area crop acreage and production estimation, mapping of salt affected soils, drought monitoring and assessment, flood mapping, watershed prioritisation and marine fisheries. This joint project is being implemented in collaboration with State and Central government user agencies.

In view of the large application potential of remote sensing and realising the need to co-ordinate and progress the activities, a set of remote sensing application studies under the Science & Technology Projects named 'Operationalisation of NNRMS' is regularly reviewed by the Scientific Adviser to Prime Minister. Some salient results are reported here.

Rice crop acreage estimation for Orissa for the Kharif season of 1986-87 and wheat acreage estimation for Haryana, Punjab and parts of Western Uttar Pradesh for 1986-87 and 1987-88 were completed. Under the drought monitoring project, fortnightly composite vegetation index maps were generated for the years 1986, 1987 and 1988. The same is being validated for assessing drought conditions. Wasteland mapping of 146 critically affected districts has been successfully completed and the maps have been distributed to the State level authorities. Urban sprawl maps of major cities of Bombay, Hyderabad, Madras, Ahmedabad, Nagpur and Bangalore have been completed. Such maps which show the growth trend of the cities, can be an effective tool in planning the expansion of cities consistent with their infrastructure which otherwise would inevitably result in unplanned growth. Ground water potential zone mapping of entire states of Madhya Pradesh and Bihar on 1 : 2,50,000 scale is in progress. Under the Drinking Water Technology Mission, co-ordinated by Department of Rural Development, 57 mini-mission districts have been selected for ground water potential mapping and the work has been completed for 51 districts. Most of the major floods which occurred during 1988 have been mapped and the maps were provided to

Central and State government authorities for immediate use. Sediment yield and priority delineation maps have been prepared for the Narmada Sagar catchment area. Forest cover mapping at National Level on 1 : 2,50,000 scale for the two year period 1986-88 being carried out by Forest Survey of India is scheduled for completion by mid-1989. Seven major projects relating to environmental impact of mining, industrialisation, coastal environment, super thermal power plants, etc., are being carried out. Under project Vasundhara, a jointly conducted effort by Department of Mines and Department of Space, digital analysis techniques have been developed to target mineralised zones using remote sensing data in conjunction with ground based data.

Response to the Department's study on integrated land and water resources management to combat

drought has been very encouraging. Based on the pilot studies and with the user feed back, the methodology has been firmed up. It is planned to carry out this study in 12 districts distributed in 12 States. This study will be conducted with active collaboration of concerned State user departments. A set of Application Validation Projects (AVP) have been undertaken in the fields of wasteland mapping, forestry, environment, landuse, topography, etc. Most of the Application Validation Projects have been successfully completed and the software so developed are being transferred to user agencies. Under this study resources maps on soil, landuse, ground water potential zone, surface water, etc., will also be prepared using satellite data and necessary ground truth. These maps will be integrated with data on rainfall, socio-economic aspects to arrive at specific recommendations on areas for ground water utilisation, ground water recharge and suggested landuse for fodder development, agriculture, afforestation, etc., as long term measures to combat drought on a sound footing.

Infrastructure and Facilities

One important component of the NNRMS is building up of appropriate facilities for visual and digital interpretation of satellite data in various user departments. Towards this, DOS has been assisting

and giving technical guidance to users to set up remote sensing cells/units/centres. Several State governments have taken steps to set up remote sensing centres for carrying out natural resources studies of interest to them. Presently, 12 States have set up operational remote sensing centres, viz., Assam, Bihar, Gujarat, Haryana, Kerala, Manipur, Madhya Pradesh, Orissa, Punjab, Rajasthan, Tamil Nadu and Uttar Pradesh. The States of Andhra Pradesh, Arunachal Pradesh, Karnataka, Maharashtra, Mizoram, Nagaland, Sikkim, Jammu & Kashmir and Tripura have already approved setting up of State remote sensing centres and are in the process of procuring essential equipment, recruitment and training of manpower, etc. The other States are actively considering setting up of such centres. The operational centres have taken part in the nationally co-ordinated projects. They are also carrying out application studies in natural resources themes of interest to the States and several maps/data base generated as a result of these projects have found use in the planning process of the States.

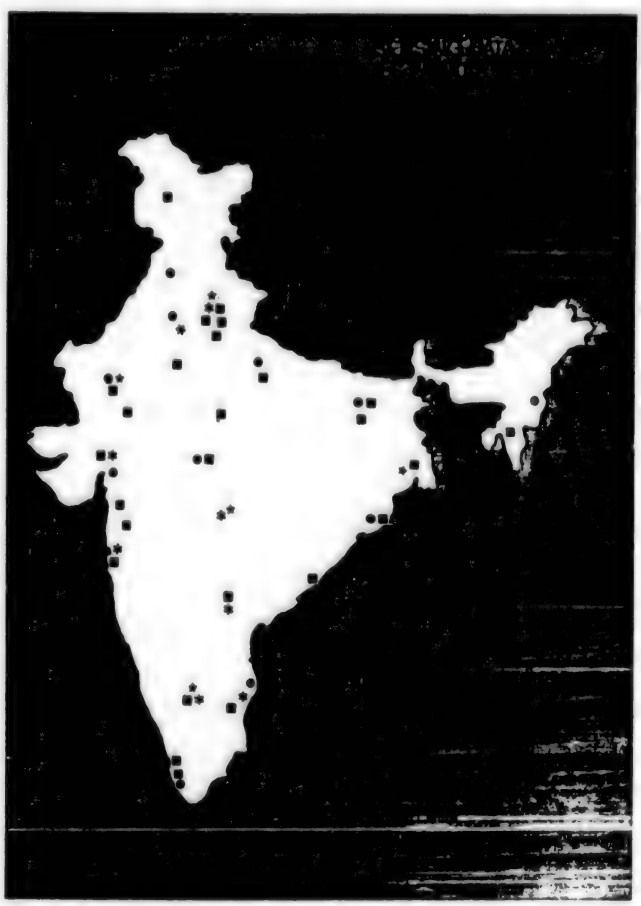
Noting the advantages of digital image processing and the increasing demand for the same among users, DOS has set up five Regional Remote Sensing Service Centres (RRSSCs) at Bangalore, Nagpur, Kharagpur, Jodhpur and Dehra Dun with partial funding by DST, DOM and ICAR. The RRSSCs have digital image processing facilities with multi-user terminals. Two Associate Centres with similar digital analysis capabilities have also been set up at Institute of Remote Sensing (Anna University) and Remote Sensing Application Centre (Lucknow) funded by respective State Governments.

The RRSSC facilities have been utilised for image processing work related to application studies such as drought monitoring, geological applications (Project Vasundhara), agricultural applications, etc. Under the drought monitoring, weekly composite vegetation index maps are being generated using NOAA-AVHRR data for the period June-September every year. In addition, the systems have been utilised to develop specific software to meet the requirements of application projects related to crops, landuse, soil, water quality, surface water, etc. In addition to providing service facilities to users, the RRSSCs have also conducted several short term training courses on digital image processing for resource scientists belonging to State government departments and Central government agencies. The RRSSCs are centrally managed by the Department of Space.

Several remote sensing facilities have also come up in Central Government Departments/Agencies such as Central Water Commission (CWC), Geological Survey of India, Survey of India, National Bureau of Soil Survey & Land Use Planning, Forest Survey of India, National Institute of Oceanography and the Centre for Earth Science Studies. In addition several universities have shown keen interest in this emerging technology and are in the process of inducting remote sensing into their regular curricula.

Training and Promotional Activities

The awareness about the potential of remote sensing among the user community and utilisation of remote sensing techniques for the optimal management of resources have increased manifold in recent years. Nearly 3,000 scientists/engineers have been trained in application of aerial/satellite remote sensing techniques by the training centres/institutions. Approximately 1/3rd of this trained manpower belong to State government departments. Training centres located in different parts of the country have a total capacity of training nearly 350 to 400 scientists per year. Training courses in new areas of application have also been designed and implemented. RRSSCs have conducted courses in digital image processing techniques.



The Indian Institute of Remote Sensing (IIRS) at Dehra Dun conducted many courses in the applications of aerial photo-interpretation and remote sensing for the officers/scientists of various State/Central government departments and also for trainees from abroad. 170 candidates completed training during the period of this report.

Taking advantage of the modern facilities available at NRSA in Hyderabad, about 7 short courses of five days to seven weeks duration were conducted there. 57 scientists/engineers from different organisations participated in these courses.

The establishment of a division of Human Settlement Analysis at IIRS, Dehra Dun, in collaboration with ITC of the Netherlands is progressing satisfactorily. The fifth 10 months post-graduate diploma course on Human Settlement Analysis was successfully completed. Nine officer trainees attended the course. A twelve weeks course in Human Settlement Analysis was conducted for 10 officers from Urban Development Authority, Colombo, Sri Lanka, during March-June 1988. A preliminary study of integrated multi-disciplinary survey of Delhi has been carried out using conventional aerial photographs, LANDSAT and SPOT data.

As part of the promotion of space technology and its applications, a number of topical seminars/workshops/symposia were held with wide national and international participation. The International Astronautical Federation Congress held at Bangalore during October 1988 had special sessions covering all aspects of remote sensing technology. There was a special current event session on drought management, a topic most relevant to the developing nations in the region. A chain of regional workshops were held on remote sensing applications to water resources. The primary objectives of these workshops were to enlighten the decision-makers and resource scientists about the potential capabilities of remote sensing in this area, particularly in view of the

recurrent drought and the need for effective management of water resources. On successful launching and subsequent operationalisation of IRS-1A, a national seminar was organised to highlight the salient aspects of the IRS-1A mission and its application potentials.

Resources Survey Projects

Several natural resources survey projects were undertaken, on behalf of users, using satellite data. Study of channel changes of Brahmaputra river in the vulnerable reaches over a ten year period (1973-84) on behalf of Brahmaputra Board, hydrographic survey of selected reaches of the river Ganga on behalf of Central Board of Irrigation and Power, mapping of landuse, land cover of Andaman and Nicobar islands on behalf of Planning Commission and natural resources survey of Andaman and Nicobar islands, remote sensing studies of geology geo-morphology, ground water, landuse and urban sprawl on behalf of the Andaman and Nicobar administration are some of the important projects completed.

As a part of the national wasteland mapping project, about 2,800 final wasteland maps have been prepared and printing work is in progress. A brochure on how to use wasteland maps has been prepared and is being distributed to all users for their reference. The maps prepared will provide the information upto village level for wasteland reclamation. Comparative evaluation of various satellite remote sensing data and aerial photographs of part of Doon Valley were made for forestry and vegetation studies using visual interpretation and digital techniques.

Mapping of vegetation types and other related landcover classes of Ranikhet region of Uttar Pradesh has been carried out by digital analysis of TM data. A project on integrated approach for planning for fuel wood and fodder development has been carried out. Suitable areas for fuel wood and fodder development such as culturable wastelands and degraded forests were identified and schemes for developing the lands for fuel and fodder augmentation have been formulated.

Monitoring ecological conditions favourable to development of desert locust outbreak/plague has been carried out. The desert locust ecological condition with special reference to vegetation development, a prime factor for locust breeding and development, was monitored through remote sensing during the monsoon season of 1987 to demonstrate the capability of remote sensing technology to delineate ecological situations favourable for locust development.

Applicability of remote sensing techniques for various aspects of glacier studies like inventory, mass balance and glacier-melt run-off is being explored. Twenty three valley glaciers are identified and their physical characteristics are determined with the help of topographic maps.

The INSAT data were processed to qualitatively estimate the extent of outgoing longwave radiation

(OLR) from VHRR IR channel, which is a reliable quantitative index of monsoon activity. The derivation of precipitation (another activity index) was refined by reanalysis of GOES data in the Atlantic Ocean. The impact of El-Nino strength on subsequent year's monsoon performance in different sub-divisions of India was shown to depend on the state (performance) of monsoon in the sub-division in the previous year, establishing the Markovian nature of monsoon. The pre-monsoon rainfall prediction for 1988 which was derived using this method for 16 sub-divisions of India, shows close agreement with the actual monsoon precipitation. A method to predict cyclone track from temperatures has been developed. Bay of Bengal tropical cyclones were recorded. The sea surface temperature determination software for use with NOAA data have been firmed up. Pattern imageries generated were compared with sea truth. Using IRS-1A LISS-I and LISS-II data, their potential in different applications have been evaluated. Methodology developed under different projects using other satellite data are being validated. The application areas where evaluations were carried out include land cover classification, forestry, urban studies, wasteland mapping and geological mapping. These studies have revealed that the quality of images from IRS is comparable to the best of the contemporary satellite for most of the intended applications.

Aerial remote sensing techniques were utilised by using instrumented aircraft over the following areas for different resources survey and related applications: nine towns of Andhra Pradesh on behalf of Director

of Town Planning, Government of Andhra Pradesh, aerial photography of Bangalore city and its environs on behalf of State Committee for house numbering systems, Bangalore, aerial photographic survey of north-eastern Jaipur and over parts of Sikkim and four test sites in Orissa, aerial photography of Pune and coastal Andhra Pradesh and parts of Satara and Ratnagiri area on behalf of Survey of India, over parts of Kasargode and Cannanore districts of Kerala on behalf of Kerala Landuse Board. Aeromagnetic survey was also carried out over parts of Andhra Pradesh covering about 12,085 line km on behalf of Geological Survey of India. In addition, about 16 projects involving different resources disciplines and covering different parts of India are at various stages of progress.

Reception, Processing and Dissemination of Satellite-Aerial Data

Reception of Multispectral Scanner (MSS) and Thematic Mapper (TM) data from LANDSAT-5 satellite and SPOT data was continued from the existing X-S band terminal. Reception of Metsat data through the new terminal was also continued. MSS and Metsat, TM and SPOT data products are being generated regularly.

The NRSA Data Centre (NDC) is the focal point for dissemination of all types of data products from IRS, LANDSAT, SPOT and NOAA satellites. IRS data products dissemination commenced from April 1988. LANDSAT and SPOT data products were continued to be disseminated to the users. The Metsat data from NOAA series satellites was supplied for the drought monitoring and a few other specific projects.

The flow of data products is being monitored on a weekly basis. The average turn around time for supply of products has been improved considerably. An information management package has been developed for request processing and monitoring of SPOT data.

The augmentation of the data products generation facility is progressing satisfactorily. The design document for the Master Flexible System (MFS) has been prepared. A computer based offline colour filming system has been installed and operationalised for MSS, TM and IRS data. The NDC-IMS system and IRS DPS have been linked through ethernet and operationalised. Construction of the new photo lab has commenced.

The aerial remote sensing facility has been effectively utilised and about 650 hours of flying was undertaken during 1987-88 season towards data acquisition on behalf of various users. About 175 hours of flying have been completed till December 1988 for the current season. An air-borne multispectral scanner will be available for remote sensing operations by early 1989. Orders have been placed for procurement of two numbers Super King aircraft : one of them has been received, while the other is expected shortly.

APPLICATIONS TECHNOLOGY DEVELOPMENT

R & D in Remote Sensing

A working model of an extended range ground truth radiometer covering the visible, NIR and MIR bands was completed and some field trials carried out. The unit used a temperature controlled PbS detector. While the basic unit functioned quite well, with a view to improve performance and the cost effectiveness, it was decided to provide separate

VNIR and MIR heads on the same unit and to do away with thermal control and introduce active stabilisation. A laboratory model was built and has been used to validate the concept.

A portable unit which conveniently and reliably acquires the data from the field instruments and is compatible with low-cost computer systems for transfer and analysis of data is a long-felt need in ground truth remote sensing data collection. Design of such a Hand Held Data Terminal (HHDT) for logging the field data has been taken up and development of the prototype is nearing completion. It is a portable battery-operated device for acquiring data from analog channels like the Ground Truth Radiometer (GTR) and store the same in the battery backed-up memory. The stored data can be retrieved or processed by connecting the HHDT with the memory card to a PC.

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A major achievement has been the development of a medium scale image processing system built around standard personal computer systems. Technology for the system named ISROVISION has been transferred to two industries and successfully productionised. The system is capable of high resolution image display and has comprehensive software for image data handling, pre-processing, enhancement, information extraction and formating functions. The key to the excellence of this system is the image analysis applications software library developed by ISRO—a menu driven user friendly software library, called "SAC IMAGE", a powerful tool for remote sensing specialists, resource scientists and managers. The image display processor VIBGYOR—2001 has all contemporary features including zoom, pan and roam. ISROVISION is the only low-cost system capable of processing input data from all the major remote sensing satellites like IRS, LANDSAT and SPOT and a variety of air-borne sensors. ISROVISION systems will meet the increasing demand for medium scale imaging processing systems from State and Central level user agencies. An advanced version of ISROVISION is also under development.

For SROSS-2/MEOSS data, software systems for generating the browse products without any correction and the standard products with radiometric and geometric corrections for oblique and normal viewing cameras were installed and tested with simulated inputs. The detailed design for the generation of precision products for oblique and normal viewing cameras and stereo products was completed.

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A multi-band Air-borne Linear Imaging Self Scanning Camera (ALISS) with spectral bands similar to IRS payload for concurrent airtruth data collection has been under development. The four-band camera system has a ground resolution of 3.0m from 3km altitude along with selectable velocity/height ratio, allowing operation over

wide range of aircraft performance parameters. The ALISS fabrication, integration and test & evaluation have been completed. The calibration data have been recorded and the unit is ready for flight use.

A seven band multispectral scanner for aircraft platforms, capable of full LANDSAT Thematic Mapper band options with 2.5 milliradian IFOV and variable V/H ratio selection has been under development. The cryogenic middle infrared detector signal to noise ratio performance was improved by the addition of cold filters to meet the requirements. Further improvements in optical layout and electronics in the light of MSS Mark II flight performance have been incorporated. The instrument characterisation in the visible MIR and thermal IR bands has been completed.

Microwave Remote Sensing Programme

The IRS-1 series of satellites operate with visible/ near infrared imaging sensors. Unlike these, microwave sensors provide all weather, day and night imaging capabilities. Thus microwave sensors have enhanced application potential in the areas of agriculture, soil, oceanography, etc. Hence, Microwave Remote Sensing Programme (MRSP) will be one of the major programmes to be taken up during the next few years. Several exercises have been carried out to seek an optimum solution for taking up the programme within given resource constraints, but without sacrificing any significant application goals or potential.

Systems studies were undertaken on Synthetic Aperture Radar, Scatterometer and Altimeter. The studies were aimed at optimising system parameters for sensors and their interdependence. Effect of satellite parameters like altitude, attitude, etc., on the performance of these sensors and their parameters was also analysed. Software for simulation and analysis of these were also developed. A software has been developed to design dispersive delay lines on Lithium Niobate and quartz substrates. Based on this software a 100 MHz expander and one 70 MHz filter have been fabricated. The measured performance of these devices is in excellent agreement with the simulated data. The X-band Side Looking Airborne Radar (SLAR) system developed at NRSA was test flown near Hyderabad in October 1988.

Preliminary actions were initiated towards acquisition and processing of the European ERS-1 data. Based on a demonstration survey carried out in 1985, several users have shown interest in airborne Synthetic Aperture Radar (SAR) surveys. Accordingly SAR surveys over Andaman and Nicobar Islands, Cauvery Basin, Godavari Basin and Orissa coast (about 65,000 sq. km.) using an X-band SAR system were undertaken in October 1988. The data quality has been found to be good and the data has been provided to other major users for evaluation of its application potential.

R & D in Communications

A 60 Mbps Time Division Multiple Access (TDMA) system which can handle upto 30 stations in the network has been developed. It is fully programmable and has facility for connecting four terrestrial interface modules to each terminal. The equipment is under test and evaluation. Parallely a simulator required for testing the TDMA equipment has also been developed. The modulator and demodulator for 60 Mbps burst mode TDMA were developed and tested. Their performance characterisation is in progress.

A Digital Speech Interpolation (DSI) equipment in which two PCM groups are interpolated digitally on 30 DSI channels at 2.048 Mbps has been developed. Two units conforming to QA guidelines were fabricated and tested. Availability of this technology for transfer was announced and good

response has been received from industry as well as prospective users. Efforts have been initiated with Telecommunication Research Centre (TRC) and Indian Telephone Industries to carry out field trials of DSI in early '89 and qualify them.

A 400 kbps demodulator required for VHRR data reception has been developed and tested. Main features of the demodulator are frequency tracking Range of $\pm$50 kHz and data acquisition time of less than one second. One 5.2 Mbps modulator required to receive IRS data was developed, tested and commissioned.

A Frame Grabber consisting of analogue to digital converter, frame store, clock generator, control logic and digital to analogue converter has been successfully developed. It has frame resolution of 512 x 576 elements. The grabbed picture is transferred to a PC via an 8 bit parallel interface between the frame store and the PC. The stored picture can be read into the frame store again for display on a TV monitor. This equipment is likely to have wide ranging applications in image processing, security systems, documentation, etc.

A Primary Multiplexing Equipment (PRIMAT) is under development. It multiplexes 120 voice channels at 2.048 Mbps, and can increase digital communication link capacity by a factor of four. Fabrication of sub-systems and testing were completed during the year.

A Fresenel ring antenna has been developed at 15 GHz. This can be used as direct receive antenna for satellite communication or for data links. Efforts are on to increase its efficiency.

Number of software packages have been developed for the projects and R&D activities. These include PC compatible structural analysis software for frame structures and a programme for generation of wind loads on mesh reflectors. □

Space Technology

The research and development activities of the Indian Space Programme are carried out at the Centres and Units of ISRO/DOS. For major projects a lead-Centre is identified and close co-ordination is maintained between the project core group at the lead-Centre and other work-centres spread around the country. Following sections briefly describe the highlights of the developments that took place during the year.

LAUNCH VEHICLE TECHNOLOGY

Augmented Satellite Launch Vehicle (ASLV)

ASLV is an augmented version of the erstwhile SLV-3 vehicle. It is designed to augment the indigenous satellite launch capabilities to place 150 kg class satellites into low earth orbit. ASLV will also validate a number of important advanced technologies needed for the larger launch vehicles of the country such as PSLV/GSLV. It uses the SLV-3 core vehicle with two strap-on booster motors to enable orbiting of 150 kg class satellites in 400 km low earth orbits. The design employs new technological elements such as vertical integration of the launch vehicle, canted nozzle boosters, a closed-loop guidance system, S-band TTC systems and a bulbous metallic heatshield.

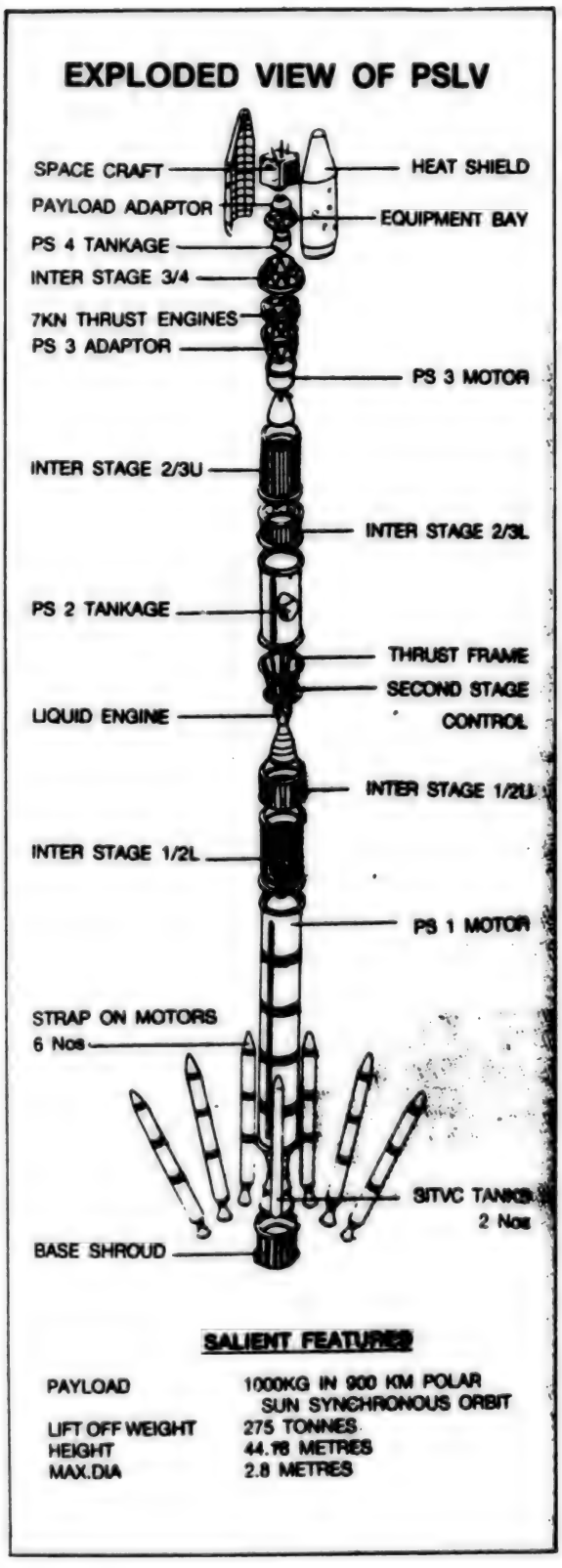
Based on the D1 launch experience, observations and the recommendations of the Failure Analysis Committee a number of modifications and improvements were incorporated in the realisation of the ASLV-D2 vehicle. With all the modifications, tests and rigorous quality control measures, the ASLV-D2 vehicle sub-systems were realised and positioned at SHAR launch site after completing relevant reviews and analyses.

The launch campaign activities progressed in a planned sequence. All the major systems underwent a series of readiness reviews. The ASLV-D2 vehicle was launched on July 13, 1988. After a smooth lift-off, the vehicle performed normally upto 46 sec.. Deviations were observed in the attitude and angular rates beyond 46 sec. The first stage ignited as expected at 48.5 sec. Later the vehicle broke up due to excessive loads built up and ultimately signals were lost at 185 sec.

Analyses of the volumnious flight data that was acquired through telemetry, tracking, etc., have been carried out by different expert teams. A failure Analysis Committee at ISRO level and an Expert Review Panel at national level have been constituted to scrutinise and review the flight observations in detail. The realisation plan of ASLV-D3 will be evolved taking into consideration the feed back from these review forums and expert teams.

Polar Satellite Launch Vehicle (PSLV)

The PSLV is being developed to achieve indigenous capability to launch operational remote sensing satellites into polar sun-synchronous orbits. It makes use of both solid and liquid propulsion stages to generate adequate thrust and control capabilities needed to place 1,000 kg class satellites at normal observational altitudes of the order of 1,000 km. The PSLV project entered the qualification phase during the year. Proto hardware of many sub-systems were realised, functionally verified and subjected to qualification testing. Third stage motor case and the fourth stage liquid engine problems reported earlier were resolved. The second stage 'Vikas' engine went through the endurance tests successfully.



Some of the specific achievements of the project during the year have been as follows:

– 15 PS-1 segments were fabricated out of which 9 were pressure tested. First PS-1 nozzle hardware with convergent was proof-pressure tested. PS-1 segment assembly was carried out for confirming interchangeability of segments fabricated at different work centres. Propellant casting on all the segments of the first stage were completed at SPROB. PS-1 sub-scale test with HTPB propellant and SITVC was realised. Three M250 sub-scale chambers were fabricated and burst tested for confirming material properties and fracture behaviour. Six PS-3 motorcases were realised and 3 cases were proof-pressure tested as part of qualification test. After rubber lining operations, propellant casting in one of the PS-3 motor has been completed. Primary and secondary cases for PS-1 igniter were realised and tests in proof hardware with carbon phenolic throat inserts were completed. Qualification tests have commenced. PS-3 igniter test with flight hardware has also commenced. Integrated test of PS-3 case with bucket flange was carried out and system level problems are being analysed. PS-3 proof motor and nozzle with PS-1 propellant composition has been made ready for the static test as part of confirmatory test for propellant burn rate. Propellant casting in one PS-0 motor was completed.

– Endurance test for 180 sec. was successfully conducted on PS-2 engine. Short (20 sec.) and long (155 sec.) duration tests with indigenous throat in PS-2 engine were conducted. PS-2 battleship propellant tank was proof-pressure tested, accepted and positioned at LPTF. Full set of battleship hardware is now ready and battleship stage assembly has commenced. PS-2 pressurisation system, POGO command module and POGO corrector module were tested at the Auxiliary Test Stand of LPTF and tests on other stage modules have commenced. Two PS-2 flight tanks were received after proof-pressure tests. Fabrication of the third tank has been completed. A number of tests on PS-4 engine using ablative cooled and regeneratively cooled chambers and triplet and co-axial injectors were carried out towards development of high performance engine

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for PS-4. Restart capability of this engine has also been successfully demonstrated. Six PS-4 titanium gas bottles were tested and cleared for system assembly.

— Three rate integrating gyros were qualified. Five dry tuned gyros (DTG) realised and two were subjected to qualification tests. Four servo accelerometers were realised and two were tested. Engineering model of on-board computer was realised. Development model of Redundant Strapdown Inertial Navigation System (RESINS) was tested and engineering model is in the final stage of assembly. Engineering model of SPINS has been integrated and test has commenced. On-board software for navigation and guidance was developed. Test and evaluation has commenced on the first unit of all the electronic packages.

— One SITVC sub-scale test was conducted successfully to evaluate system performance and multiport injection. Two full scale SITVC injection valves were assembled and testing has commenced. SITVC flight version tanks were fabricated in house and aluminium coated at BHEL. Two sets of SITVC toroids were fabricated and one set burst tested successfully. Two proto type assemblies of PS-2 engine gimbal control system were realised and one set tested during the long duration test of PS-2 engine. Six proto types of flex seal were fabricated and structural test and actuation trials were completed. The test results were reviewed and go ahead for further fabrication given. The proto package of PS-4 engine gimbal control system with brushless torque motor is ready and tests commenced.

— Panel tests and boat tail tests were conducted for the performance evaluation of the zip-cord explosive bolt and rubber bellows towards heatshield jettisoning system development. Heatshield full scale mock-up was fabricated for development tests. Ullage rocket jettisoning test using mechanical pin pusher devices were carried out. Engineering Models of PS-1 separation system and PS-2/PS-3 separation system were fabricated.

— The first set of interstage hardware such as 2/3U, 2/3L, 3/4, Thrust Fame, 1/2U, 1/2L and core base shroud were fabricated at HAL. Assembly of heatshield hardware is in final stages of completion. The second and third sets of payload adaptor, PS-3 adaptor and water tank were fabricated and the assembly of other structures is in progress. An acoustic test of base shroud assembly was carried out to evaluate the lift-off acoustic impact on base shroud and electronic packages.

— The 60T X 4 and 15T X 4 hydrodynamic bearings were developed, tested and the bearing system assembled for dynamic tests. All hardware except strap-on base ring are ready for dynamic test.

— All assembly fixtures and handling equipment for hardware, sub-system/system and stage assembly have been realised and commissioned. All interface drawings and integration layout drawings were finalised. Thermal and acoustic protection system designs were completed. Mimic graphic system on checkout computer was developed. Indigenous silver-zinc cells were qualified. Battery assembly and qualification are in progress. Engineering and qualification models of Serial Checkout Units (SCOUT) were realised and tested. Computers for the hardware-in-loop test were received and installed. Electrical umbilical scheme for PSLV was reviewed and finalised. PSLV-IRS interface requirements including cut-out requirements were finalised.

— Mobile service tower erection to full height of 75 metres was completed. Umbilical tower erection is nearing completion. Erection contract was awarded for liquid stage launch service facilities.

— PCMC radar mount was fabricated and erection commenced at SHAR. Components for the radar were fabricated and delivered by BEL.

— An Electronic Beam Welding facility was commissioned and welding trials conducted.

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A 3-dimensional co-ordinate measuring machine was commissioned at SIF, Valiamala. A 1,000 kVA generator was commissioned at Valiamala Complex. A 500 kVA generator and a 3D CMM were added at REPLACE. A precision centrifuge was commissioned at ISTF.

— Wind tunnel noise characterisation studies are in progress. Heatshield ejection altitude and the launch azimuth have been finalised. Single point failure modes were analysed by a committee and the recommendations have been implemented. Mission salvage plan finalised. Studies were carried out to finalise mission sequence which will ensure adequate structural margin under extreme launch environment.

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– Two PDP computers have been linked in high speed DMA mode to share, in real-time, continuous simulation of PSLV trajectory. Closed loop guidance algorithm has also been integrated into the simulation package. A graphic package has been developed for digital simulations using a colour graphics terminal.

Geo-synchronous Satellite Launch Vehicle (GSLV)
Indigenous capability for the launch of INSAT-II class of spacecraft is planned to be achieved in the 1990s with the development of the Geo-synchronous Launch Vehicle (GSLV). GSLV is being configured in such a way that the elements and infrastructure coming out of the PSLV programme are maximally used. GSLV will later incorporate a high energy cryogenic upper stage for enhanced performance. Initial efforts for the development of the cryogenic engines/stages for such an application, are underway.

During the current year mission design, analysis and vehicle sizing for a large number of GSLV configurations using a variety of stage modules have been carried out and the options narrowed down for final selection.

In the area of cryogenic technology heat sink version of sub-scale engine was realised and tested using liquid oxygen and gaseous hydrogen. Three versions of the regeneratively cooled sub-scale engine were designed and the fabrication of the engines was initiated. Injectors for the above engines have been realised. In addition, a brazed corrugated water cooled thrust chamber with an injector to develop around 3 tonnes thrust is being realised to study the combustion characteristics. Detailed design and engineering of the test facility for sub-scale engine was completed and facility elements ordered. Civil works for the facility is nearing completion. Long lead items like Helium/Hydrogen liquifier have been ordered. Indigenous development of Oxygen Free High Conductivity (OFHC) copper, porous plate for injector and titanium alloy gas bottles continued. Two sub-scale titanium alloy gas bottles were successfully developed. Design of the turbopump for a 12 tonne class engine has been initiated. A full scale injector for 12 tonne engine has been realised in order to establish the feasibility of fabrication.

SOUNDING ROCKET PROGRAMME

The Operational Rohini Sounding Rocket Programme was continued with developmental projects to support rocket meteorology, upper and middle atmospheric research and flight systems evaluation. More than 95 sounding rockets were produced during the year under the programme. Sounding rockets were launched from the SHAR, TERLS and Balasore ranges.

85 RH-200 rockets were launched with chaff payload for meteorological and middle atmosphere experiments. Two RH-200 dual thrust motors were static tested with good results. Software studies on single stage RH-200 rockets for smoke trail flights and

technology development flights for re-entry and reuse are in progress. Work on spherical probe ejection system is continuing.

As a part of the pre-launch ground station evaluation exercise one RH-300 MK II, with ASLV transponder sub-systems, was launched successfully prior to the ASLV-D2 launch. One RH-560, two Centaure and two RH-300 rockets were also flown with scientific experiment payloads.

Regular weekly launchings of M-100 rockets continued from TERLS with standard meteorological payloads. Since the beginning of this programme, more than 1,000 rockets have so far been launched from TERLS.

SATELLITE TECHNOLOGY

The progress of the Indian Remote Sensing Satellite (IRS) and that of INSAT satellite programmes and related technologies are covered under 'Space Applications'.

SROSS Satellite

The Stretched Rohini Satellite Series (SROSS) programme is directed towards supporting missions using 150 kg class satellites for space science, technology and application studies. The SROSS satellites will be launched into a nominal 400 km circular orbit by the ASLV launchers. During the year the SROSS-2 satellite was developed, fabricated, qualified and readied for launch. SROSS-2 carried an experimental remote sensing payload MEOSS developed by DFVLR, the West German Aerospace Agency. The satellite carried a Gamma Ray Burst (GRB) detector as a secondary payload. MEOSS consisted of a Monocular Electro-Optical Stereo Scanner for generating stereo images of the earth towards applications in meteorology, geology, forestry and the like. The GRB detector was intended to monitor celestial gamma ray bursts in the range of 20-3000 keV. SROSS-2 was launched on ASLV-D2 in July 1988, but was not orbited due to the failure of the launcher.

SROSS-3 is identified to carry a joint NPL-PRL experiment in aeronomy. Following studies on the configuration of SROSS-3, a configuration review was conducted in September '88. Development of bi-stem deployment mechanism for the payload sensors was carried out. SROSS-4 will carry an X-ray astronomy payload jointly developed by ISRO and TIFR. Initial studies on the configuration of SROSS-4 were carried out. A number of payload combinations were also studied for a possible payload on the next launch of ASLV.

TECHNOLOGY DEVELOPMENT

Research and development activities were continued in a variety of technological areas to support the organisation's launch vehicle, satellite and applications programmes. Highlights of these activities carried out during the year are reported here.

Propellants and Chemicals

Development of HTPB based propellant for stage motors and igniter propellants was completed. RH-200 size building block motors were successfully static tested. Pressure cure to achieve flaw free casting was successfully implemented in CDB processing incorporating a smokeless high energy additive. Development of pedcoat liner for modified

PS-1 and PS-3 stages was completed. A new method to evaluate the burn rate of propellant pre-mix slurry for PSLV propellant was developed and successfully demonstrated. The visco elastic characterisation of PS-1 and PS-3, rheological characterisation of igniters of PS-0, PS-1, and PS-3 were completed.

QC studies on EPY 1061 coating system was completed and one PS1-SITVC flight tank was successfully coated with this. Aging studies on EPY 2163 and EPY 2173 were completed. RTV silicon potting compound was used in PS-0 motor segment joint which performed satisfactorily in static tests. Synthesis and qualification of polyaramides by phosphorylation technique was completed. Polyurethane based on HTPB was made and the thermal properties were evaluated. Systems suitable for melt processible, soluble, mandrel compounds were identified and two formulations finalised. Scaling up of PIM-750 to 25 kg batch level and polyamic acid to 30 kg batch level were carried out and both the processes were QC certified. Development and qualification of rigid foam mandrel for PS-1 igniter case was successfully completed and the mandrels are in use.

Microcellular polyurethane elastomers were developed for incorporation in 'Jaipur foot' and field trials were carried out. Polyurethane elastomers were developed and supplied to the sounding rocket programme for vibration clamping in the payload. Laboratory dry-jet spinning process for polyaramide monofilaments using vertical coagulation bath was optimised.

Development tests in proof hardware were completed for all PSLV stage motor igniters. PS-0 igniter

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alongwith safe/arm, ETA and TBI was evaluated in one static test. Under the development of linear bellow system for PSLV heatshield, 10 short length weight simulated panel jettisoning tests were conducted successfully. One full scale functional test for PS-0 destruct system was conducted on simulated target dome using monolithic cast charge. PS-1 destruct system test was conducted successfully. Cable cutters supplied for solar panel deployment mechanism in IRS-1A and SROSS-2 functioned satisfactorily. Glass seals and vacuum brazed components for satellite pyro devices were processed.

An expert system for identification of polymers and chemical elements by analysing spectral data obtained from spectroscopes has been developed.

Materials

A silver graphite brush material was developed and 400 brush blocks were made for slip ring assemblies. Towards development of AA2014 alloy for PS-3 adaptor, ring rolling was completed for 8 rings and these were successfully heat treated to T652 condition. In the indigenisation programme of AA2219 aluminium alloy, mechanical properties were evaluated on the welded samples, and rings were developed by ring rolling technique. For the development of the Mg-Li alloy, a melting and casting set-up was designed and fabricated. Three forgings in AZ31 alloy castings from Mg-alloy AZ92 & ZE41 were made for various projects.

Developmental work is under progress for realising a porous injector disc for cryogenic engine. In the development of Al-Ir-Mg wrought alloy with Ti02 particulates, cold rolling sheets upto 0.1 mm were realised and heat treated. Al-Si and 7075 A1 alloys in the ribbon form were made.

Studies were conducted to identify the cause of cracking of Cirseam welds in maraging steel PS-1 segments while fabrication at one of the work centres. Hemispherical forgings were made for PS-2 gas bottles and welding trials were carried out on Ti-5A1-2.5Sn ELI grade material. The material characterisation laboratory, the heat treatment and welding facility, metallography facility and testing and analysis facility catered to the requirements of projects and R&D groups. Ag-Zn cells of 1,3,5,10 & 15 Ah capacity were processed for battery level qualification. In the development of modified ESR 15CDV6 material, two RH-200 size motor cases were fabricated and burst tested.

Composite nozzles for ASLV-D2 motor cases, stage igniter cases, pressure bottles, wire tunnels, etc., were processed. For the PSLV project the composite PS-3 motor case was redesigned. The first phase of the facility augmentation to realise a production target of one composite motor case per month is completed. PS-1 primary and secondary igniter chambers and PS-3 igniter chamber qualification tests were completed and regular production started.

For the INSAT-II (TSP) project, the solar panel was redesigned and two panels were made. A CFRP yoke was developed and is undergoing testing. C/C

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and C/S antennae were developed and are undergoing qualification tests. SADA cone was fabricated and tested successfully. Pultruded sections for astromasts were supplied to project for testing. Structural models of the pressurant tanks were also fabricated.

The CNC filament winding machine was modified to cater to the winding requirements of PS-3 motor case. Detailed processing studies were conducted on polyamide resins developed in-house. Technology was transferred to one exernal agency for RH-200 ablative liner moulding and impregnation of ablative material with phenol resin.

Magnesium-lithium alloy material has been selected for the covers of the electronic packages of INSAT-II TS. As this is a highly reactive material, the material has to be well protected from the environment. Chromating and gold plating processes have been successfully developed for this material.

Aerospace Structures

The general purpose Finite Element Analysis Software package (FEAST) was improved and augmented. Finite element analysis of ASLV interstage structures, analysis of booster motor grain for internal pressure loads and the overall static stability analysis of the vehicle were conducted.

Burst pressure prediction and structural integrity assessment for PS-1 motor case and fracture analysis and testing of PS-1 sub-scale chambers were carried out. Non linear stress analysis of N_2O_4/UDMH baffles of PS-2 tankages, burst testing of PS-2 water tank toroid, proof testing of titanium gas bottles and fracture analysis and testing of PS-4 propellant tanks were completed. For PS-3 motor case static stability analysis of the skirt, structural analysis of the PS-3 flex nozzle systems and qualification testing of the motor case were done. Theoretical and experimental vibration analysis of PSLV 1/5th scale model for various configurations was also completed. Structural model of the equipment bay deck plate was fabricated.

Design and analysis of the INSAT-II TS solar panels, C/S band antenna and SADA cone were carried out. Initial configuration studies were carried out for the GSLV programme. Design/analysis of RH-200 dual thrust motor-case, fin, fin shroud and modified grain were completed.

Investigations on the design of inserts in different configurations for satellite applications are in progress. Characterisation of carbon prepreg was initiated. Non-destructive testing studies on honeycomb sandwich panels were conducted using holographic interferometry. Acoustic emission and residual stress measurement technique applications for structural testing are being evaluated.

Mechanical and Thermal Systems

A large number of precision mechanical systems for the ASLV, PSLV and RSR programmes were fabricated. Close interaction and systematic co-ordination was maintained for fabrication of a gamut of mechanical systems at various work centres in the private and public sectors.

Most of the qualification tests on INSAT-II TS optical solar reflectors have been conducted. Study was conducted to identify the critical elements of the hydride cooler for applications in cooling detectors of remote sensing satellites at very low temperatures. Materials and components procurement is in progress. Study of metal-coated kapton and teflon tapes for use as optical tapes having different optical properties are in progress for providing flexibility in implementing the thermal control system on spacecraft.

Development of the IR simulation technique for carrying out the thermal vacuum performance and thermal balance tests on spacecraft has been initiated. Studies on various elements like heaters, heat flux sensor, etc., were carried out. Software for estimating the heat flux on any surface of the spacecraft from different heat sources is under development.

Propulsion Systems

Solid Propulsion Systems

An air breathing propulsion system was successfully hot tested using Mg based fuel-rich propellant. A

propulsion module with discrete air in-take was designed and the performance estimated.

Nozzle thermal design analysis of PSLV strap-on motor with HTPB propellant was completed. A sub-scale nozzle, simulating SITVC ports of PS-1 nozzle, was successfully static tested. Flex seal development is nearly complete and intensive trials and elaborate testing were done. A monolithic silica-phenolic liner was developed for PS-4 ablatively cooled engine which performed satisfactorily in a hot test of 425 sec. duration. Revised design for the thermal protection system for PSLV heat-shield and thermal insulation of PS-1 was completed. Thermal design/analysis of antenna dish of PCMC radar and insulation design for the convergent of retro ullage rocket of PSLV were also completed.

The experimental programme for evaluating the combustion instability response of PS-3 propellant composition was completed. Estimation of ignition transients for PS-3 with different nozzle diaphragm pressures was made.

Liquid Propulsion Systems

The 'Vikas' engine underwent a successful 180 seconds endurance test at the principal test stand. Including this endurance test, the cumulative duration of engine tests in 1988-89 was 557 seconds which included two nominal duration tests of 150 seconds. In one of the tests, the engine gimbal control package, hot gas roll control systems and indigenous silica phenolic throat were evaluated. One series of turbopump tests for a cumulative duration of 385 seconds to study the offdesign and the cavitation characteristics was conducted.

Second stage battleship propellant tank was realised and preparations for the battleship stage assembly have been completed. Three flight tanks, two flight quality water tanks and first set of thrust frame and interstage structures have been realised. Dynamic mock-up tank realisation is nearing completion.

CDR of the fluid control systems was conducted after successful completion of the development tests. Fabrication of the qualification hardware and the hardware for stage development and qualification tests are in progress.

Component level performance tests on the engine gimbal control systems were completed. One integrated system test with the 'Vikas' engine was also completed. The development tests of the hot gas roll control system, a technology critical item, has been completed in engine and turbopump test series. Fabrication of qualification and flight models have been initiated. Extensive tests were conducted on the POGO corrector system, POGO modulator and the POGO command system module at the auxiliary test stand using water as a simulated fluid. The POGO corrector system parameters have been finalised after the above test series. Preparations for the test of the system coupled with turbopump at the principal test stand have been completed.

All the development problems of the high performance fourth stage regeneratively cooled engines have been solved and the engine configuration frozen. Three endurance tests each for a duration of 530 seconds have been completed as a part of the development programme. The fabrication of engines for qualification and flight is in progress. As a standby to the regeneratively cooled engine an ablative chamber engine was also developed and it underwent a successful nominal 425 seconds hot test.

The fourth stage battleship hardware were realised and preparation for battleship stage assembly is in progress. First interstage hardware was completed

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and the second is nearing completion. The fabrication of titanium alloy flight tank is in progress at HAL. Part of the development tests of the pressurisation system was completed. Fabrication of qualification and flight hardware is in progress. The reaction control system thrusters have undergone developmental trials and the reaction control system test modules have been realised.

Elements for the structural model (SM) of the INSAT-II TS Propulsion System have been realised. Realisation of elements for electrical thermal model (ETM) is nearing completion. Qualification model of titanium alloy propellant tank with the propellant management device has been realised and the qualification programme is in progress. Realisation of flight model of the tankages is also in progress. Latch valves for flight models have been ordered. Indigenous development of latch valve is continuing.

The High Altitude Test (HAT) facilities for LAM and AOCS engines were commissioned and development test of the thrusters is in progress. Thruster hardware for the qualification programme are being realised.

Sensor Systems

Three coating technologies, namely, high efficiency antireflection coating for IR optics, front surface mirrors for VHRR telescope optics and black chrome coating for photo masks were successfully developed. High efficiency antireflection coating has better than 99% reflectivity and it has undergone space qualification tests successfully.

The development of infrared filters in 14 to 16 micrometre was taken up during 1988. This work involved more than 50 layers of coatings and a number of developmental models have been fabricated. This activity will be pursued further in the coming years also. Software for design of various types of thin films have also been developed. Another new item which was taken up during the year is the development of thin film strain gauge for use in pressure transducers. Development models have been successfully fabricated.

A number of design software have been developed for optics design. Some of the major designs completed include high resolution camera optics for panchromatic camera of IRS-1C, design of multielement lens for LISS-II camera, and design of specialised lenses for test systems in laboratories, like null lens. During 1988, totally 10 different design configurations were made using computerised design tools.

Fabrication and testing of 200 mm dia RC Telescope for INSAT-II TS VHRR was carried out. Both the breadboard and engineering models were completed and supplied for integration. Fabrication of flight model is in progress. These telescopes involved generation of aspheric surfaces of very high quality for primary and secondary, and coating of surfaces with high reflectivity coatings. The total process for

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fabrication has been successfully completed. A number of sensor components and special mirrors were also fabricated.

The breadboarding of laser ranging system is in progress. Various components required for the system have been fabricated. Testing of the solid state laser and amplifier has been completed. Development of the star calibration system for PCMC radar has been completed. The telescope system and computer system have been integrated. Three units are getting ready for test and evaluation.

Work on development of an on-board processor to interface various attitude sensors has been initiated. Software for removing systematic errors by on-board computation has been generated. Hardware development has been initiated for use in IRS-1C. Development of precision magnetometer is in progress. The first model has been fabricated and is undergoing qualification tests. Engineering model of the sensor is being fabricated.

Avionics Systems

Inertial Guidance Systems (IGS)

Post flight analysis of the performance of control and guidance systems in ASLV-D2 were completed and necessary changes to be incorporated in the systems for D3 flight have been identified.

After completing the performance validation of Redundant Strapdown Inertial Navigation System (RESINS) for PSLV on an engineering model, fabrication of a qualification model has been taken up. An engineering model of Stabilised Platform Inertial Navigation System (SPINS) with improvements essential for meeting the PSLV specifications is under fabrication. Multi-layer (six and four) PC boards manufactured by Indian industries have been used in engineering model of the on-board guidance computer. Software development in navigation, guidance and digital autopilot areas, their validation through digital and hybrid simulations and readiness of check-out systems are keeping pace with hardware development.

Rate integrating gyroscopes (beryllium version) have been qualified for the use in navigation systems for ASLV/PSLV. Similar qualification tests on indigenous dynamically tuned gyroscopes and servo-acclerometers are nearing completion. A few design improvements were made on the developmental model of the laser gyroscope which works on fringe shift nulling technique.

Flight packages of Reaction Wheel Assembly (RWA), Solar Array Drive Assembly (SADA) and Redundant Attitude Reference System (REARS) supplied for IRS-1A satellite are performing well in the orbit. Dynamically tuned gyroscopes in REARS and slip ring unit in SADA are two major indigenously developed items.

Hardware realisation for INSAT-II TS also made considerable progress during the year. Simulation and structural models of reaction wheel/momentum wheel assembly, solar array drive assembly, inertial reference unit and VHRR scan mechanism were supplied to the project. Fabrication and tests of electrical thermal models are nearing completion.

Electronic Systems

Performance of Telemetry, Tracking and Telecommand (TTC) system packages have been satisfactory in ASLV-D2 flight. Detailed post flight analysis has been completed. Fabrication of packages for ASLV-D3 flight and standby systems has been initiated.

Qualification tests on first set of proto packages fabricated for PSLV is nearing completion. Additional qualification models needed for making one full set of equipment bay sub-systems are undergoing final integration and tests. Procurement of electronic components has been completed for the fabrication of flight packages for PSLV-D1.

A critical design review (CDR-II) was conducted on all sub-systems for the APC-REX project. Most of the flight hardware packages are undergoing test and evaluation. On-board computer software is being validated by means of an engineering model hardware.

Engineering model of a general purpose 16 bit on-board computer was realised based on bit slice

technology. It has most modern features like floating point arithmatic hardware, MIL-STD-1553B serial I/O, self diagnostic capability, high level language compilers like Pascal, C, etc.

Performance of the receiver part of C-Band coherent transponder was tested by means of a breadboard model at single pulse interrogation frequencies. Feasibility studies have been initiated for the realisation of on-board PCM telemetry packages in ASIC version.

A packet Telemetry System with CCSDS format has been developed for the data handling of SROSS-3 at a data rate of 100 kbps. After the design and fabrication of the R-S coding encoder, the decoder has been designed and the corresponding decoding algorithms have been coded and checked. The software developed for this purpose has been tested for different codes with errors introduced. As part of telemetry test station, the documentation system working around a DM board installed within the PC has been successfully used in testing and decommutating the INSAT-II TS engineering model telemetry package and also other similar formats from a PCM simulator. Further tests are in progress.

A very light weight circularly polarised dual mode conical horn having a circular symmetric pattern with a beam width of 9° and a gain of + 19.0 db has been developed. The horn is qualified mechanically and electrically to suit the specifications of INSAT-II TS as a Global Horn. A 4 pole combline filter with 40 MHz bandwidth and 1.2 db insertion loss has been developed for use in INSAT-II TTC transmitter filter. A 4 pole TEM mode filter with 50 MHz bandwidth at a centre frequency of 6420 MHz with 1.5 db insertion loss has been developed to be used in the Rx Chain. An IF bandpass LC filter with elliptic approximation has been designed and developed for use at MCF, Hassan,for satellite TV reception. A 5 watt C-band transmitter has been designed and developed for checkout operations of INSAT-II TS.

A C-band SAR antenna system for satellite microwave imaging is being developed using microstrip planer array. A S-band feed has been developed to handle 2kW power with dual port for simultaneous operation of transmission and reception in circular polarisation. This feed has been installed at the Lucknow ground station.

A computer programme has been developed to generate solar cell parameters. The programme is useful for generation of solar cell/panel I-V characteristics at any temperature and intensity in the orbit. The programme has been tested for various conditions of the solar cell operations. The programme is presently in use for estimation of solar array power output. A flyback converter working at 50 KHz using an optocoupler for feedback sensing was developed. This unit besides having a very good regulation has an overall efficiency of 80%. A power supply for ion thruster is under design and development.

Hybrid microcircuit (HMC) versions of dc/dc converters and output delay circuit are being

developed. Qualification of output delay circuit is nearing completion. Push-pull type dc/dc converters have undergone second breakdown energy test and thermal resistance measurement tests.

An automated communication transponder check-out system has been developed for the integrated satellite level characterisation of communication transponders. The system consists of two synthesised signal generators, microwave power meters, a high resolution microwave spectrum analyser, a low frequency network analyser, and a custom-built unit called the test selection matrix. All the system instrumentation are fully programmable via the IEEE-488-1978 bus using a desk-top computer employed as the instrument controller. The above system can automatically measure various parameters. The measurement software has been developed in a high level language and employs a modular approach.

Control Systems

Two sets of proto engine gimbal control system packages for the PSLV second stage were developed and subjected to hot tests successfully. Five sets of extended stroke actuators, three sets of brushless actuators and the associated electronics were developed and fabricated for the flex nozzle control system applications. A Secondary Injection Thrust Vector Control (SITVC) system package utilising the ASLV booster motor was realised and tested. This has provided valuable inputs for the design of the SITVC system for PSLV. Prototypes of the propellant tanks and toroids of the SITVC system for the first stage of PSLV have been completed and qualification programme is in progress. An engine for the roll control system has been developed. Development of 60T hydraulic bearings is in progress.

A laboratory model of a 10mN Hg ion thruster operations were pursued to ascertain its long term behaviour. About 800 hours of operation with about 1000 ON/OFF cycles have been logged without significant performance deteriorations.

The liquid sloshing during LAM burn mode of INSAT-II TS was represented by equivalent model and simulation for LAM burn mode has been carried out. The representation by equivalent mechanical model was validated by a finite element method using the 'FEAST' software.

Fabrication of a scale model for drop test, to find out the time constant for divergence during the spinning phase of INSAT-II is nearing completion. Fabrication of spin up and release mechanism and supporting structure has been completed. AOCS of INSAT-II TS will use hybrid microcircuit thruster and relay drivers as did the SROSS-2. Routine batch production of these HMCs is now established. 16 thruster drivers and 12 relay drivers were fabricated and screened for each of the ETM and simulation models of INSAT-II TS AOCS.

A magnetic suspension with two passive radial bearings and one active axial bearing was assembled and its performance characteristics were measured. The influence of the various component values of the control electronics on the stiffness, stability, etc., of the suspension were studied in detail. A new magnetic suspension employing two number of three loop radial bearings was designed. All the parts of the suspension were fabricated. The assembly and testing of the above suspension is in progress.

A simulation model for the PSLV third stage flex nozzle control system was developed and tested. A short period dynamic model was developed to design the PSLV 'Load relief' control. The affect of wind was also studied.

Flight Dynamics and Mission Planning

Extensive trajectory simulation studies were carried out on ASLV-D2 performance as part of post flight analysis. Studies on PSLV separation systems using Monte Carlo method have been completed. A scheme for mission salvage action, in case abnormal performance of vehicle occurs during flight, has been worked out. Normal load distribution data was generated for PSLV. Mission design analysis and vehicle sizing studies were carried out for a large number of GSLV configurations with a variety of stage motors. Performance studies and air intake analysis were continued for air breathing rocket. First cut design studies were conducted on Lifting Re-entry Vehicles (LRV) using modified GSLV configurations which are capable of performing

scientific, application and recovery type objectives in the same mission. Preliminary design cycle studies were completed on the design of an Aero-assisted Orbital Transfer Vehicle (AOTV) configuration compatible with PSLV for recovery of the payload or spacecraft from geo-stationary orbit. It involves detailed studies on performance capability, aero-coefficients under different environments, orbital decay, aerodynamic heating and thermal protection systems, etc.

Computations were carried out for flow past PSLV bulbous heatshield. Semisteady state solutions were obtained for shock wave and boundary layer resolutions at transonic mach numbers. A computer programme was developed for the solution of thin layer Navier-Stokes equations for axi-symmetric flow at an angle of attack and further work is under way. A study has been initiated to formulate algorithms for parallel computing. Development of finite element and finite difference programmes for heat conduction problems is in progress. Numerical solutions for initial value problems using cubic and quintic splines with an analysis of convergence were carried out. A programme was made operational to obtain the Earth-Mercury transfer of space vehicles using Venus swing-by method.

New test techniques have been developed for flow visualisation at hypersonic speeds and continuous pitch mode of force measurements. Flow visualisation tests were carried out on various models of GSLV candidate options. Force measurement studies were carried out on cone-cylinder models at hypersonic speeds and on Lifting Re-entry Vehicle (LRV) models.

An elaborate sequence of events (SOE) covering pre-launch, launch and initial phase mission operations of IRS-1A was generated. Full set of operational software system has been developed for satellite orbit determination and prediction using both analytical and numerical integration methods; for attitude (orientation) determination and prediction for both spin and 3-axis stabilised satellites; and for determination and implementation of orbit transfers and orbit maintenance of satellites. A set of orbit-attitude-manoeuvre utility packages to cover a wide spectrum of user requirements and various aspects of mission analysis and advance study have also been developed.

Following advanced studies have also been undertaken: analytical methods for obtaining transfer orbit parameters for chaser vehicle to rendezvous to target vechicle; lunar launch window analysis; lunar and interplanetary analysis; preliminary studies on choice of deep space network; collision probability of spacecraft with man-made debris; on-board attitude estimation using star sensors; solar sailing and orbit selection and analysis for microwave remote sensing missions.

Aerospace Mechanisms

A number of evaluation tests relating to the PSLV systems were conducted. These include heatshield band separation tests and interstage band tension-tests. The zero 'g' facility, pneumatic facility and open well test facility were commissioned. Work on thrust phase simulation facility is in progress.

Design of a nut type canister deployment mechanism for deployment of flexible solar arrays was completed. The boom required for electric field experiments on SROSS-3 was designed. Qualification tests on permanent magnet DC motors with integral gear head are in progress.

Bonded film lubrication using Molybdinumdisulphide with a silicate binder was qualified for use on-board spacecraft deployment mechanisms. This has been successfully applied to solar panel deployment mechanism components of IRS, SROSS-2 and INSAT-II TS Satellites. Acceptance testing including the adhesion and friction tests under ambient,

vacuum, post thermovac and humidity conditions was completed satisfactorily. IRS solar panels, adopting components lubricated by this technique, deployed satisfactorily in space.

Lubrication of Ti alloy hinges using sputtered MoS_2 film was taken up and after tests with the basecoatings like Ni, Cr, TiN, etc., the processing parameters were reviewed and improved film quality was obtained. A batch of 6 stainless steel specimens has since successfully gone through the tests.

PRODUCTION, ASSEMBLY, TEST AND SIMULATION FACILITIES

Propellant Production

The Solid Propellant Space Booster Plant (SPROB) completed processing of PSLV first stage (PS-1) motor systems and third stage (PS-3) motors for static tests. As many as 53 proof motors with PS-1 propellant composition were also processed. For dynamic load testing nine strap-on motor dummy segments were processed. The 15 MeV linear accelerator has been reinstalled and commissioned. Erection of second vertical mixer has commenced and is expected to be operational by March, 1989.

The rocket propellant plant produced 208 propellant grains of various sizes amounting to about 26 tonnes. This includes five PS-0 segments, one AS-2 and 92 Rohini rocket propellant grains. 110 pieces of insulation/liner, 600 pieces of mouldings and 1.6 tonnes of rubber compound were processed. The Ammonium Perchlorate Experimental Plant (APEP) produced 129 tonnes of ammonium perchlorate and 200 litres of strontium perchlorate. APEP has enhanced the capacity of the plant to 220 tonnes per annum by progressively switching over to titanium substrate anode system.

Five tonnes of HTPB RESINS and about 2 tonnes of other polymers and chemicals were produced in the Propellant Fuel Complex (PFC).

500 kg of Hydrazine and 250 kg RFMA were produced in-house. A commercial-scale plant for production of 90 tonnes of UDMH and 10 tonnes of MMH was established in industry and regular production started. A process for production of precipitated silica from rice husk was completed and qualified. The following pyrotechnic systems were produced and supplied: 5385 squibs, 183 cartridges and 184 igniters for in-house use. 149 sounding rocket motors were charged in the Rocket Motor Charging Facility. Charging of ASLV and PSLV igniters were carried out as required.

Electronic Production

Fabrication of inertial guidance, TTC and power packages for ASLV-D2 standby systems was completed during early part of the year. Production support was extended to qualification models of PSLV. Detailed production planning is undertaken for the fabrication of packages for next ASLV flight, PSLV-D1 flight and the INSAT-II TS project. Total number of packages fabricated during the reporting period consists of more than 120 single card packages and over 50 complex multicard packages.

Nearly 3,000 Printed Circuit Boards (PCB) have been produced in the in-house PCB facilities to cater to the needs of all projects. Trial fabrication of 6 layer multi-layer cards were undertaken. Fabrication of a large number of thick hybrid microcircuits and 95 microstrip cards were produced by MIC Facilities for the use of PSLV, IRS and INSAT-II TS Projects. Beryllium Machining Facility at New Bombay continued production of precision components for inertial sensors.

Work areas in electronic fabrication and test facilities were converted into electrostatic discharge (ESD) protected zones for avoiding hazards due to ESD problems. Optimisation of process parameters for wave soldering was carried out. A Computer Aided Design (CAD) work station established last year was augmented by the addition of three more work stations and a host computer system for local area networking. All the work stations and the host system are capable of supporting the design of multi-layer PC boards and hybrid microcircuits on stand-alone mode also.

Transducer Production

Utilising the in-house facilities 800 absolute pressure transducers, 50 differential pressure transducers

and 120 temperature sensors were produced to meet the requirements of various programmes. Development work on transducers to meet the future requirements was continued. Qualification of thin film transducers was completed and field trials have been initiated. Development of pressure and temperature sensors for cryogenic application has been initiated. Development of precision pressure transducers for PSLV requirements was completed. Four transducers were qualified to meet the INSAT requirements.

Liquid Propulsion Test Facilities

The Principal Test Stand (PTS) was operational and a long duration endurance test of the Vikas engine for 180 seconds was conducted as a part of the engine test compaign. The cumulative duration of testing was 557 sec. A turbopump test series for about 400 seconds was also conducted at PTS to study the cavitation characteristics of turbopump. The test facility was also utilised for the testing of hot gas roll control system and engine gimbal control system. The test facility was augmented to carry out POGO corrector tests. The test stand is being modified to carry out stage battleship and stage development and qualification tests.

The Auxiliary Test Stand was utilised for calibration of Vikas engine injectors, testing of pressurisation system of PSLV second stage and POGO modulator, POGO command module and POGO corrector system. The test stand has been rigged up for umbilical system field tests to simulate the umbilical system separation at the launch pad. The pressurisation systems chain of fourth stage of PSLV was tested in the gas generator test facility after making the required modifications to the existing facility. The sea-level bay of the liquid upper stage test stand was fully operational. Three endurance tests of the regeneratively cooled engine of the PSLV fourth stage were successfully completed. Two ablative engine tests were conducted in addition to a partially regenerative cooled engine. High altitude test bays for LAM and AOCS engine testing of INSAT-II TSP in simulated altitude conditions were commissioned and made operational. The LAM engine was tested for short durations in high altitude facility. The AOCS engines were tested in both continuous and pulse mode operations in the facility. The high altitude test bay for the testing of upper stage engine of PSLV was fully assembled and commissioning trials are planned for the first quarter of 1989. A high pressure air compressor was added to the high altitude facilities for reducing the turn around time between tests.

The cyrogenic sub-scale test facility realisation is in progress. Civil works and the test stand structure have been completed. The single element test facility was modified for the testing of heat sink version of sub-scale engine using LOX and gaseous hydrogen. Heat sink version engines were tested with side mounted and centrally mounted electric igniters in the above facility.

The test facilities at Thumba were utilised for the short duration tests of PSLV liquid upper stage engines, the qualification of indigenous catalysts for monopropellant thrusters of ASLV class of control power plant engines and the testing and characterisation of LAM and AOCS engines. The micro thruster test facilities at LPSC, Bangalore, were utilised for the acceptance testing of 1N monopropellant thrusters for satellite applications. The vacuum chamber for testing 11N class of thrusters was integrated to the existing facility.

Static Test and Evaluation Complex (STEX)

Major thrust at STEX during the current year is related to ASLV and PSLV related activities. STEX carried out inspection and assembly of sub-systems like nozzles and igniters with ASLV-D2 stage motors. Sound and vibration level measurements were made during ASLV-D2 flight and the data analysed.

Segment assembly and static testing of PS-0 subscale dry joint motor in six component test stand with SITVC has been conducted successfully. Inspection and assembly of 9 PS-1 hardware were carried out and subjected to proof-pressure testing. Final assembly and evaluation of PS-1 single and six component test stands are in progress. As a part of augmentation to the assembly-cum-static test facility to meet the requirements of GSLV booster testing, the test bed extension work has been carried out.

Equipment erection at PS-3 test facility has been completed. Vacuum chamber and diffuser were vacuum tested. Testing and evaluation of 130 measurement channels have been completed. Fabrication of thrust frame and diffuser lining is in progress.

RELIABILITY AND QUALITY ASSURANCE (R & QA)

The role of R & QA in the Space Programme needs no emphasis. The R & QA groups at the ISRO Centres and Units supported all the programmes in the areas of quality control, quality assurance, reliability analysis and test and evaluation. Product Assurance Boards of the PSLV and the INSAT-II TS projects met periodically and reviewed the progress of activities.

Test and evaluation of flight packages for ASLV-D2 and RSR programme was carried out. Qualification tests on several PSLV and INSAT-II TS project sub-systems were conducted. Software was developed for PSLV packages, for simultaneous multiple testing of RSR timers and for the testing of some LSIs. Evaluation of components subjected to vacuum, cold soak and humidity was also carried out. An additional laboratory was set up for temperature and mass calibration activities. Reliability assessment and derating analysis of avionics packages, INSAT-II TS sub-systems and ASLV-D2 were carried out. Qualification test plans pertaining to chemicals, propellants, composites, liquid engine components and satellite mechanisms were prepared. Failure analysis for 16 components of ASLV-D2 and 22 PSLV qualification model packages were performed. The failure analysis laboratory was augmented with the addition of an ESD sensitivity test equipment. Six training and certification courses were conducted on hi-rel inter-connection techniques.

Quality surveillance at external work centres was carried out for all projects. Investigative studies on the ultrasonic examination of weldments and forgings were continued.

Qualification of following indigenous technologies was completed: black chrome coating on glass substrates, gold plating on stainless steel substrates and chromating Mg-Zn, Al and Mg-Li alloys. Heat treatment studies on ultra-light Mg-Li alloys were undertaken. Most of the tests required for qualification of in-house multi-layer boards were completed. Radiation dose profiles for INSAT-II TS were calculated and updated.

A methodology for evaluation of tracking network performance routine preventive maintenance and review procedures was evolved, in order to realise the required overall availability and operational reliability of the integrated TTC Network. 673 tests were carried out on various propellant segments, rocket motors and assemblies. A new dedicated flex seal test facility was commissioned.

SAFETY SERVICES

The role of safety in Space Programme needs no emphasis as the development and production of launch vehicles and satellites involve the manufacture, storage and handling of large amount of explosive propellants and toxic chemicals, use of high pressure systems, radiation sources, etc. The safety groups at the ISRO Centres and Units continued to render support to divisions and projects in achieving their goals without any major accidents. The technical advisory committee to ISRO Safety Office met regularly and reviewed the safety activities. Important safety activities carried out during the year are as follows:

Centre Safety Committee and ISRO Safety Office carried out hazard analysis for the new processes and programmes such as PS-1 and PS-3 motor processing, environmental impact analysis of static tests of large size solid propellant motors, cryogenic sub-scale engine tests, etc., and recommended suitable safety measures.

Safety clearances were given to more than 30 new processes and buildings involving handling of hazardous materials in various Centres and Units of ISRO after appropriate evaluations.

All the safety measures were reviewed and implemented during the ASLV-D2 launch. Specifically indepth reviews of integration operations of the stage motors and pyro systems, and check-out activities were carried out to identify problem areas and the additional safety measures required. Detailed reviews were also carried out for the solid propellant processing facilities at SHAR for PS-1 segments casting. Reviews were carried out for the liquid propellant test facilities at Mahendragiri. Several safety appraisal visits were also made by safety groups at Centres/Units.

Guidelines on "Safety in Construction Works—General," "Safety in Construction Works—Equipments," and "Safety in Use of Corrosive Acids," were issued as part of the safety awareness programme. Regular inplant safety training programmes on important topics such as chemical safety, fire prevention and protection, electrical safety, material handling, first-aid, etc., have been conducted at the Centres and Units. As part of National Safety Day celebration, a booklet on "Home Safety" was brought out and distributed to all employees. Safety groups at Centres and Units organised safety essay, safety slogan and safety poster competitions. Safety films were also regularly screened.

Analysis of the accidents and incidents were carried out and safety measures recommended to prevent recurrence of accidents. A summary analysis report on accidents was brought out and follow-up actions identified. Periodical medical check-up for the personnel involved in handling of hazardous materials was continued. Detailed reviews for all the new buildings and facilities established and major equipment commissioned during the year were carried out from fire safety angle and suitable fire prevention and protection systems were recommended and implemented. □

Launch Support, Tracking Network & Range Facilities

Launch support to all ISRO missions is provided by the ISRO Range Complex (IREX). Facilities of IREX are located at SHAR, TERLS and Balasore. ISRO Telemetry, Tracking and Command Network (ISTRAC) operates an integrated network facility comprising TTC stations at SHAR, Trivandrum, Bangalore, Lucknow, Car Nicobar and Mauritius. The multi-mission Spacecraft Control Centre (SCC) of ISTRAC is located at Bangalore.

ISRO RANGE COMPLEX (IREX)

ASLV Launch Complex

Based on the recommendations of the post flight analysis of the D1 flight, necessary modifications and improvements were incorporated in the launch complex facilities. All the systems were tested and evaluated for the required performance characteristics before the start of the D2 launch compaign. The launch compaign itself was conducted smoothly.

The performance of all the launch facilities and the ground support systems was satisfactory during the ASLV-D2 launch. The gamut of flight data was analysed after the launch and all the inputs needed for the post-flight analysis of the D2 mission were provided to the appropriate expert committees.

PSLV Launch Complex

Fabrication and erection of the 75 m structure for the PSLV mobile service tower and that of the umbilical tower were completed. Launch pedestal, door, sliding roof and sliding mechanisms for the door have also been completed. The bogie structure fabrication is in progress. Procurement of electronic sub-systems, erection of the pedestal, fabrication and erection of the platforms, and the assembly of the bogie system are all in various stages of completion. Procurement actions for the liquid propulsion stage related services and facilities are in progress. Data and control cables connecting the launch pad and MCC/LCC have been laid.

The Precision, Coherant, Monopulse C-band (PCMC) radars project has entered the erection phase. Major works completed during the current year include the realisation of one radar antenna system. The system is undergoing test and evaluation. Works related to second and third radar systems are in

progress. With regard to servo system, the system integration and testing with data processing sub-system (DPSS) in instrumentation container has been completed successfully, while wiring and fabrication works for second and third servo units are progressing satisfactorily.

Purchase Orders for all the critical sub-systems have been released. Telescope system and feed systems have been received. Two feed systems were integrated with reflectors and performance testing was completed. Development of software packages required for star calibration and on-axis tracking is in progress.

Launch Support for Sounding Rockets

Nearly 150 sounding rockets were launched from SHAR, TERLS and Balasore ranges during 1988. These include daily launchings of 35 RH-200 rockets from TERLS as a part of the equatorial wave compaign, weekly launchings of RH-200 rockets from Balasore under the IMAP, an RH-560 rocket launched from SHAR for the study of spread-F phenomenon and an RH-300 MK II rocket launch for evaluation of the performance and readiness of ground station systems prior to the ASLV-D2 launch.

ISRO TELEMETRY, TRACKING AND COMMAND NETWORK (ISTRAC)

Launch and initial phase TTC operations of IRS-1A were smoothly accomplished by the ISTRAC network. TTC support was provided by the Bangalore, Lucknow and Mauritius stations of ISTRAC. In addition, support was hired from three foreign stations for monitoring the initial phase operations. Scheduling of operations, network co-ordination, data flow control, satellite health monitoring, orbit and attitude determination and planning & execution of the orbit manoeuvres are carried out from the Spacecraft Control Centre (SCC) at Bangalore. Round-the-clock spacecraft operations and control are continued since the launch of IRS-1A.

Tracking and simulation exercises were conducted by SHAR, Car Nicobar and Trivandrum ground stations and flight dynamics software simulation exercises were carried out for ASLV-D2/SROSS-2 flight readiness. Pre-launch and launch phase mission operations support for ASLV-D2/SROSS-2 was provided by SHAR, Car Nicobar, Trivandrum and Bangalore ground stations as per plan.

Ground network envisaged for PSLV support includes S-band TTC stations at SHAR, Trivandrum and Mauritius. SHAR-I and Trivandrum Ground stations have been operationalised for ASLV-D2 mission. Major electronic systems required for SHAR-II ground station have already been procured and the ground station is likely to be commissioned by December 1989. The S-band receive only station in Mauritius, now being utilised for IRS-1A mission, is being augmented for simultaneous transmit/receive capability. PCMC radar planned for the PSLV down range support is under development and is expected to be commissioned in the TTC station at Mauritius by December 1989.

Scheduling, tracking, data pre-processing and orbit determination support were continued for the Aryabhata, Bhaskara I & II and RS-D2 satellites. Routine tracking support was provided for the three NOAA satellites. To enable multi-mission support, redundant antenna systems have been commissioned at the Bangalore TTC station.

Preliminary studies were made at the Laser and Optical Tracking Facility for identifying a ground based laser system and the payload requirements to track microwave remote sensing satellites.

SHAR COMPUTER FACILITIES (SCOF)

SCOF serves the needs of real-time and off-line computing and data processing for all rocket launches. During the year a new operational, real-time data acquisition and processing system was developed and commissioned. This was successfully used for meeting the requirements of ASLV-D2 mission. Two additional computing systems were commissioned for the real-time support of the PSLV mission. □

Space Sciences

PHYSICAL RESEARCH LABORATORY (PRL)

Infrared Astronomy

The 1.22m diameter Infrared telescope has been installed at Gurushikhar, Mount Abu in Rajasthan, at an elevation of 1693m from mean sea level. The computer controlled telescope has a 1,220mm dia parabolic primary, three hyperbolic secondaries and three flats for coude focus. Work on testing and calibration of the systems is in progress to make the telescope fully operational.

First scientific observations using this telescope were carried out in November 1988 for stars with no polarisation and for stars of known polarisation. Two objects R AQUARII and HR 4049 (B9.5) were observed in U, B, V and R wavelength band, observations on HR 4049 (B 9.5) showed weak wavelength dependence of the degree of polarisation and strong wavelength dependence of position angle which indicate that it could be a binary system.

Solar and Plasma Astrophysics

Interplanetary scintillation data from the three radio telescopes installed by PRL at Thaltej, Rajkot and Surat are used for the estimation of the velocity of the solar wind. Efforts are under way to make near real-time estimation of the solar wind velocities using newly developed microcomputer-based digital data acquisition systems and modems with dedicated telephone lines connecting the three sites.

A Micro computer system has been installed at the Thaltej field station during this year. The system is being used as a stand-alone computer for software development for solar wind velocity measurement and 'g-map' (mapping the plasma turbulence in the interplanetary medium) programme.

The INDO-US co-operative project launched in July 1987 between PRL and NOAA envisages imaging of the interplanetary medium by measuring scintillations from a large number of radio sources around the Sun. For this purpose, the present antenna array (10,000m^2) of the radio telescope at Thaltej is being doubled. This will be used in conjunction with the 32 double-channel receivers with a provision of continuously monitoring scintillating fluxes of hundreds of radio galaxies, on daily basis.

A comprehensive study of the quasi-longitudinal and quasi-transverse approximations for waves in a magnetoplasma was carried out. In recent past some doubts were raised about the validity of these approximations and some alternatives to these have been suggested. The present study shows that the traditional zero order, first order and second order angular approximations are clearly superior to the alternatives suggested, specially for the waves having frequencies larger than the ion gyrofrequency, but smaller than the plasma frequency of the medium. These results are applicable to wave propagation in the solar corona, Earth's ionosphere, etc.

Solar Studies from Udaipur Solar Observatory

A new methodology has been developed for predicting when an H-alpha flare will be a proton or cosmic

ray flare. It is found that the probability of a flare being a proton flare or even a cosmic ray flare is very high under certain conditions.

Detailed software programmes have been developed for fast and accurate determination of heliographic co-ordinates of sunspots. Sunspot proper motions and build-up of magnetic energy in a solar active region have been studied. A 8.2 metre diameter astronomical dome for the high resolution solar spar telescope has been completed and the 12 feet filter, time lapse photographic camera and TV camera have been moved to the new telescope house on the island.

Planetary Atmospheric Sciences

A dayglow photometer capable of making line intensity measurements has become operational. This photometer is the first of its kind and can measure OI 630nm airglow intensities which are even less than 0.1 per cent of background continuum.

In a joint ISRO-DFVLR programme for studying the F-region of the ionosphere over SHAR, an RH-560 rocket carrying Langmuir Probe of PRL and resonance cone and plasma potential probe of DFVLR, FRG, was launched on May 1987 during daytime. The data has been analysed. It is seen that while the resonance cone observed the layer, the Langmuir probe did not, indicating qualitative differences between the two techniques of measuring electron density. Electron temperatures measured by the resonance cone experiment indicated an enhanced maximum around 180 km. It was also found that there is a finite drift of electrons parallel to the magnetic field in 250-300 km region. Electron beam density was found to be 1% of the ambient electron density and the beam velocity was about an order of magnitude higher than the thermal velocity of electron. This is a new observation and is likely to throw more light on the phenomenon of equatorial spread-F. Kilometre scale size plasma density irregularities with amplitudes of 10-20% were observed in 240-300 km region. There are also the first observations of day time equatorial F-region irregularities.

A Centaur rocket with Langmuir probe and two pairs of double probes for electric field measurements was successfully launched from Thumba on May 27, 1988 under strong electrojet conditions. Electron density and electric field structures were measured for studying the relationship between the two parameters and to understand the mechanism of generation of plasma irregularities.

An RH-560 rocket with Langmuir probe and electric field probes was launched from SHAR in October, 1988 to study the nature of the electric fields and the associated plasma irregularity structures in the equatorial spread-F. The payload configuration and the sensor arrangement was similar to the one to be flown in SROSS-3 satellite. A new digital ionosonde was operated at SHAR to monitor the onset of spread-F.

Photo absorption and fluorescence cross-sections for sulphur-di-oxide have been measured in the 200-235 nm spectral region using an intense argon mini-arc light source. The photo absorption cross-sections were measured in an absolute fashion. Also, the fluorescence quantum yield for sulphur-di-oxide was obtained as a function of incident photon wavelength in the 200-235 nm spectral region.

A meteorite shower fell in Torino, Italy, on 18th May 1988 and within a few days it was made available for scientific investigations, providing a unique opportunity to study short lived radio isotopes produced by cosmic ray interaction. This

work was done in collaboration with Institute di Cosmogeofisica, Torino.

For most of its geological antiquity the Earth has witnessed fluctuations in its climate—of varying intensities and on varying time scales ranging from annual to decades to hundreds of thousands of years. These climatic fluctuations and related Earth surface process have been recorded in the sediments—both terrestrial and marine. A programme is being pursued to understand various aspects of global change in different time scales. For example oxygen isotope stratigraphy of calcitic shells deposited by organisms living in ocean waters (both surface and deeper) in the sediment cores from the Arabian Sea and the Equatorial Indian Ocean demonstrate that: the Arabian Sea was cooler by 2°C about 18,000 years ago, coinciding with the most recent episode of glacial maximum (LGM); the surface water temperatures 1,25,000 years ago were similar to those at present; the sea level was lower by 150 m during the LGM; and the biological productivity during 18ka-13ka was lower than the present. This is attributable to a reduced upwelling of deeper waters and consequently suggests a reduced monsoonal activity in that period. Further studies are underway to quantify these changes and to provide a gross record of long-term changes in the Indian monsoon during the past.

Extensive effort to understand short term fluctuations in the Indian monsoon were also made by analysing the deuteriun/hydrogen ratio in the tree cellulose extracted from annual rings of trees.

A comprehensive programme to understand the origin and evolution of the Rajasthan desert was initiated.

A related aspect of the global change is the understanding of major catastrophies in the Earth's history and the related mass extinction of the biological species. Studies on the records of chemical signatures of possible asteroidal or cometary impacts on Earth over geologic time scales (in India) coupled to paleontological evidence suggests that biological extinction is a prolonged process. Thus unlike the geochemical boundary the biological boundary is considerably diffused. In this programme, extensive geochemical studies are underway to examine various alternative modes of geochemical enrichment of metals at the K/T boundary.

Archaeology and Hydrology

Studies have been initiated to reconstruct the quaternary climates in Kashmir and Kumaon Himalayas, Gujarat and Rajasthan in Western India and Nilgiris in Southern India on time scales of 10^2-10^5 years. As part of this programme, it is proposed to raise undisturbed sediment cores from lakes having well defined catchments in different regions. For this purpose, a 12 m Mackereth corer has been designed and fabricated.

The corer has been successfully tried during field operations in October 1988 at Naukuchia Tal, Nainital. Two cores of 6 m length were raised and these are being subjected to detailed investigations for estimating the length of the geological record through radiocarbon dating and the sediment character through sedimentological and mineral magnetic studies. Parts of the core samples have also been given to Birbal Sahni Institute of Palaeobotany for investigations.

A combination of mineral magnetics and carbon-14 dating of sediment cores from filled up parts of three of the Sal Tal complex of lakes has been done to study the changes in the sedimentation rate under different types of catchment conditions.

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Theoretical Physics

It has been recently realised that Cellular Automata offer excellent models for the study of systems with a very large number of degrees of freedom. We have shown recently that any one dimensional deterministic cellular automation could be considered as equivalent to a map on the unit interval. Since such maps have been extremely well studied in the last decade, it is hoped that statistical properties of Cellular Automata could be established easily.

The study of the quantum analogue of a classically chaotic system is in progress with the purpose of establishing relation with random matrix theory. Large scale computations have been recently completed and the results are being analysed to demonstrate the inherent statistical behaviour.

The study of classical Yong-Mills (SU(2)) plasma has been initiated by scientists at PRL. The basic objective is to look for qualitatively new features in the plasma due to its non-abelian character using non-perturbative methods. A new periodic non-abelian longitudinal oscillation has been found which alternates with the usual abelian mode. It is also shown that when the non-abelian terms become large, chaotic behaviour sets in.

Considerable progress has been made in understanding the basic physical mechanisms of variability of monsoon on the 30-50 day time scale. The problem has been studied using highly simplified systems of equations and analytical techniques as well as using a low resolution global spectral model and numerical techniques. When the release of latent beat is included we obtain an eastward propagating mode with a scale of wave number one, period of 25 days and a two-layer structure which has large resemblance with the observed 10-50 day mode. We have also obtained an expression for the northward phase speed and get reasonable values. This is apparently controlled by the horizontal and vertical shears, convective heating and coriolis and Rossby parameters.

Work on a novel way of looking at monsoon, i.e., the application of the theory of chaos and strange attractors to the monsoon rainfall time series was continued. The rainfall of several sub-divisions was studied. It was found that there is an underlying attractor of fractal dimension.

A programme has been started to study in detail the nonlinear effects associated with the magnetosonic waves driven by upper hybrid waves. The first part of the work has now been completed. Results show, for the first time, that when the wave propagation is near the magnetosonic speed, there exists a new class of localised solutions—solitons—for the wave fields. The plasma density perturbation is either compressional or rarefaction type depending on

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whether the propagation is super-magnetosonic or sub-magnetosonic. The upper hybrid wave field has an antisymmetric structure in contrast to the symmetric structure reported in the literature so far. The next part of the work is in progress.

SPACE PHYSICS LABORATORY (SPL)

Aerosols and Atmospheric Lasers

Altitude profiles of aerosol extinction observed with ruby lidar were used to study the temporal variations at different altitude regions. It was observed that in the middle troposphere, the monthly variation of extinction is small while the nature of variations in the upper and lower troposphere are distinctly different.

The wavelength dependence of aerosol optical depth does not follow any monotonic variation. It shows a complex structure revealing modal type of aerosol number density size distribution.

A programme to obtain aerosol size distribution function from spectral aerosol optical depth measurements has been developed.

Boundary Layer Physics

Tristatic Doppler Sodar which gives information on the strength of temperature turbulence, wind speed and direction in atmospheric boundary layer has been made operational.

Data obtained from a Monostatic Doppler Sodar being operated since 1984 reveals formation of a thermally modified Convective Internal Boundary Layer (CIBL) after setting in of sea-land breeze. Major seasonal variations have been observed in thermal plume activity in relation to surface heating, humidity and wind.

Vertical wind velocities exhibit positively skewed non-gaussion distribution during convective conditions indicating vertical gradients in turbulent kinetic energy.

Atmospheric Dynamics

The meteor trial radar data recorded since 1984 has been reformatted into hourly files. The winter and summer season data is being processed to study the seasonal variation of atmospheric oscillations in the 70-100 km region.

The NOAA-9 satellite TIP data was recorded for about 60 days at the rate of at least one pass per day. The radiances data from the NOAA-9 meteorological satellite recorded at Trivandrum was analysed to study the large scale temperature oscillations in the stratosphere over low latitudes.

Using classical theory of atmosphere tides, the diurnal and semidiurnal tidal fields of pressure, temperature and winds in the middle atmosphere over Thumba, Visakhapatnam, Ahmedabad and Delhi were computed for possible comparison with observations at these stations.

Using a multilayer approximation of the altitude variation of the real atmospheric temperature and winds, the reflection co-efficients of the equatorial waves have been estimated for January and July wind conditions in the 20-90 km height range. These computations could explain many observed features of the equatorial waves in the middle atmosphere.

Ionosphere-Magnetosphere Physics

The VHF backscatter radar was operated for 5 days in a month for obtaining the Doppler velocity and signal strength variations of the 2.7 m scale size irregularities in the equatorial electrojet and F regions. The radar was also operated for a few hours under strong signal conditions using the new 4 x 15 switchable beam interlaced phased array.

A new digital ionosonde similar to the one at Trivandrum with identical crossed delta antenna has been installed at SHAR Centre for scientific studies as well as for providing back-up data during rocket flights. The ionosonde is in regular operation from September 1988.

Detailed study of the counter electrojet events using the data of horizontal component of the earth's magnetic field recorded at three equatorial stations, namely, Trivandrum, Addis Ababa and Huancayo clearly shows that the counter electrojet event occurs almost at the same local time at all the three

stations during the months of November, December and January contrary to the earlier results that the longitudinal extent of the counter electrojet events is restricted to a narrow longitudinal belt.

Atmospheric Technology

The developmemt of a 4x15 switchable beam interlaced phased array has been completed. The performance of the array was tested using the electrojet signals and also using the Sun as a radio source when it transited through the antenna beam in the month of September 1988.

TECHNICAL PHYSICS DIVISION, ISAC

A two star photometer was fabricated and tested on the 40" telescope of the Vainu Bapu observatory at Kavalur and the performance has been found satisfactory.

During November 1988 a major international campaign, christened 'The Whole Earth Telescope' was undertaken which involved the photometric observations of white dwarf oscillations using data collected from several observatories located at different longitudes of the globe. This would help determine different periods in the system and their time variations. This is a new technique to determine the age of the galactic disc and thereby the age of the universe.

During November 1988, the white dwarf binary V471 Tau and the ZZ ceti star G29-38 were observed using the two star photometer and a clemens interface unit supplied by the University of Texas. Nearly 33 hours of time series data spread out over several nights was collected and is being analysed.

A portable versatile photon counting system was designed, developed and tested for photometric data collection. The system was checked at Kavalur and found satisfactory

An alternate hardware and software design of a data handling system for two star photometry was also developed in-house. The performance of this new interface to the personal computer has been verified using pulsed signals as inputs.

The C-14 telescope at ISAC campus was used to observe Alfa Ori and TY Pyx. A number of RS CVn fields were selected and identified for future observations.

A software to demonstrate the supernova explosion was implemented on PC-XT. The low resolution periodograms of the HD83368 data were co-added to obtain high resolution periodograms.

INDIAN MIDDLE ATMOSPHERE PROGRAMME CONTINUATION (IMAP-C)

IMAP-C is a multi-institutional and co-operative scientific programme for the investigations of the radiative, dynamic, physico-chemical and electrodynamic phenomena and processes taking place in the middle atmosphere between 10-100 km height region. The multi-agency programme is funded by government departments such as the Council of Scientific and Industrial Research, Department of Electronics, Ministry of Environment and Forestry, Department of Science and Technology (including the India Meteorological Department), Department of Space and University Grants Commission with DOS as the nodal agency for its implementation. Over 215 scientists from about 20 national laboratories, research institutes and universities are participating in the programme. During the year the following major experiments and investigations were completed: An aerosol campaign was conducted in two phases with identical balloon and rocket borne pair of instrumentation. The first set of balloon and rocket measurements were conducted during April 1988, before the monsoon season and the second set during November 1988, after the monsoon season. These measurements of aerosol concentration profiles and size distributions were complimented by ground based LIDAR and multi-wavelength radiometer observations on both the occasions. In addition balloon borne ozone concentration and conductivity profiles were also measured as supporting information. The data collected from this successful campaign are being analysed.

As a sequel to two Equatorial Wave Campaigns carried out earlier, the third and final campaign to investigate the vertical propagation of equatorial waves and its interaction with the meanflow prior to and during the monsoon season was conducted by launching 44 RH-200 rocket from Thumba during May-July, 1988. To study the horizontal wavelengths of these equatorial wave oscillations, regular and near simultaneous balloon radiosonde/ rawinsonde flights were conducted from Port Blair, Minicoy and Trivandrum. The data is being analysed.

The first experiment to measure nitric oxide concentration profile under IMAP was conducted in a Centaure rocket successfully launched from Thumba on May 4, 1988. The payload was developed by NPL in collaboration with University of Tokyo. The rocket also carried other payloads for measuring Lyman α (Alpha) flux, electron/ion densities, etc., in the middle atmosphere for a comprehensive study of the D-region (60-100 km) of the middle atmosphere.

A high altitude plastic balloon carrying chemical release payload and spherical probes was successfully launched from Hyderabad on March 4, 1988. The photographic data of chemical cloud has been utilised to derive the eddy diffusion co-efficients at several altitude points upto about 29 km.

The second Workshop on IMAP scientific results held at Vikram Sarabhai Space Centre (VSSC), Trivandrum, during April 1988 was attended by over 100 scientists actively participating in the programme. The workshop highlighted the major thrust of the investigations, results obtained and possible future directions. A number of new and interesting results were reported in a total of about 60 presentations.

Following the workshop, a combined meeting of Scientific Advisory Committee (SAC) and Programme Management Board (PMB) of IMAP-C was held to formulate the recommendations of the workshop on the activities in the remaining period of IMAP-C as well as its follow-up during post IMAP period.

MST RADAR PROJECT

The Mesosphere, Stratosphere and Troposphere (MST) Radar Project has been taken up for establishing an MST Radar as a major national facility for atmospheric research in the country. The MST Radar provides high resolution data on atmospheric winds on a continuous basis, which is essential for the study of the different dynamic processes of the atmosphere. This information helps in the understanding of the climatic and weather variation especially those due to transport of minor constituents, generation of gravity waves, cyclones, storms and monsoon circulation. The MST Radar Project is jointly funded by the Department of Electronics, Defence Research and Development Organisation, Department of Science and Technology, Department of Environment, Department of Space and the Council of Scientific and Industrial Research. ISRO/DOS is the nodal agency for establishing this national facility. ISRO has awarded a contract for

the design and development of this radar system to the Society for Applied Microwave Electronic Engineering Research (SAMEER) of the Department of Electronics. Gadanki village near Tirupati in Andhra Pradesh has been chosen for locating this facility.

Land acquisition and tendering of civil works is completed. Development of the different sub-systems of the radar is in progress at SAMEER, Bombay. Engineering test results on the prototypes of the major units and sub-systems of the radar were seen by the MRC (Monitoring and Review Committee). Characterisation of mutual coupling effects of an array of 3 element Yagi antenna was completed leading to 3 sub-array testing. The prototype of real time data acquisition sub-system is completed and system software development is in progress in the supermico computer system procured for this purpose.

The facility will be tested in the ST mode as a first step and will be upgraded to the MST mode by the time of commissioning. All activities leading to the testing in ST mode are progressing satisfactorily. The MST Radar Project Office of ISRO is located at ISTRAC, Bangalore.

ADVISORY COMMITTEE FOR SPACE SCIENCES (ADCOS)

ADCOS continued its efforts in promotion of selected Space Science Research Programmes and arranging support for these. A compilation on instrumentation needs for meeting the requirements of ongoing and planned atmospheric research and monitoring programmes in the country has been prepared. ADCOS is further examining the manner of implementation of these instrumentation requirements. ADCOS has also prepared a consolidated plan for rocket and balloon based scientific research activities envisaged during the Eighth Plan period. □

Sponsored Research

ISRO initiated the Sponsored Research Programme (RESPOND) in 1976 to establish a strong interaction between ISRO and the academic institutions in the country to carry out jointly research, developmental and educational activities of relevance to the Indian Space Programme. The programme is aimed at developing large research base at the academic institutions, manpower training, building infra-structure facilities and nurturing indigenous capability to support the space research programme. The major activities identified under the RESPOND programme are research and developmental activities in space science, space applications and space technology areas, establishment of Space Technology Cells, support to education programmes, conferences, seminars, symposium workshops, publication activities, etc. Since initiation, the RESPOND programme has supported as many as 220 research projects at 80 institutions which included universities, IITs, national laboratories, regional engineering colleges and public sector industries. As many as 1,200 scientists and engineers are involved in ISRO supported projects at academic institutions distributed all over the country.

The projects that have been completed during this year include: the study of star spots on the surface of the solar type RSCVn type binaries, investigation of monsoon of South Asia, theories of early universe, environmental impact on autotrophs and heterotrophs of Chingleput district, model for atmospheric transmittance and radiance, impact of education of rural and urban population through video tapes, and weldability evaluation of special steels. The results, applications and technology generated in these projects are disseminated to ISRO scientists for appropriate use in their programmes.

Projects initiated during this year include study of astrophysical molecules, investigation of cosmological models, maser effects of space plasma, ionospheres of the outer planets, study of equatorial thermosphere, study of monsoon dynamics, study of burning rate of composite propellants, development of an ejector system for thrust augmentation of rocket, and the behaviour of structures under large acoustic loading. A project was also initiated at the Vikram Sarabhai Community Science Centre at Ahmedabad to generate educational materials in space science, rocketry and study of satellite orbits for the benefit of teachers and students. Another project to study the space and environmental law was initiated at Jawaharlal Nehru University, Delhi, to provide the necessary inputs to ISRO regarding space law and to organise workshops to train people in this subject.

The three space technology cells at IISc, Bangalore, IIT, Bombay and IIT, Madras have become operational and are carrying out research and developmental activities in selected advanced space technology areas. Projects at these cells include optimal rendezvous and docking studies, computer modelling of conformational features in poly-butadiene, accurate determination of temperature and thermal stresses in elastic bodies, development of novel organometallic and metals containing

polymers, end capping of isocyanates for propellant binder systems, migration of chemical ingredients in solid propellant grains, development of expert systems, study of effects of ultrasonic vibrations in the heat treatment of some age hardenable alloys, studies on supersonic combustion, studies on siltation of reservoirs based on remote sensing techniques, geo-modelling of a mineralised area through integration of remotely sensed, geo-physical and geo-chemical data, and training/education/teaching materials development.

In addition to the research projects, ISRO also supported a number of conferences/symphosia, workshops, publications and joint educational programmes of relevance to the Space Programme.

In the next five year plan the RESPOND activities will be energised by establishing two Space Technology Cells and increased research projects in the thrust areas of direct relevance to ISRO projects. The ISRO-academic institution interaction acts as an important element for generating new research and developmental activities in the advanced areas of space application and technology. □

Space-Industry Partnership

As an act of policy, Indian Space Programme has been seeking an active participation of Indian industries to support the execution of its projects. With a view to forge this linkage into a sustaining relationship for mutual benefit and growth, a two-way partnership between the Space Programme and Indian industry has been evolved. This two-way linkage involves the transfer of advanced technologies developed in the Space Programme to industry and the provision of technological consultancy from the Space Programme to industry on the one hand, and the utilisation of industry's own technological potential and expertise by the Space Programme on the other.

ISRO's technology transfer scheme promotes and supports the commercialisation of technologies developed in the Space Programme for applications in various national sectors. The three major purposes served by this scheme comprise (i) meeting the requirements of Space Programmes and projects through the buy-back of products produced by industry as a result of technology transfer; (ii) servicing the rapidly expanding space applications markets in India generated by the Space Programme in the areas of satellite communications, TV and radio broadcasting, meteorological services, remote sensing for natural resources survey and management, and (iii) exploiting the full potential of the indigenous technologies developed by the Space Programme for multifarious spin-off applications.

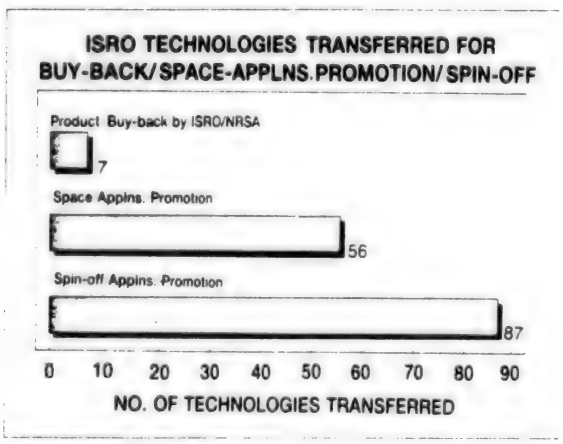
ISRO's technology transfers cover a wide spectrum of technologies/applications. Upto the end of December 1988, 150 distinct technologies have been licenced by the Indian Space Research Organisation (ISRO) and National Remote Sensing Agency (NRSA).

ISRO's technological consultancy scheme aims to share with industries and other R&D institutions, the extensive technical expertise and infrastructure developed in ISRO. Launched in 1982, this scheme has evoked good response from industry as well as other organisations in the country. Under ISRO's technological consultancy scheme, 8 new consultancy projects have been undertaken during 1988.

Indian industry's direct role in serving Space projects has shown the continuing trend of growth both in terms of technological complexity and quantum of work. Industry is playing an increasingly important role in various tasks related to the ongoing Space projects.

TECHNOLOGY TRANSFER

During 1988, seventeen new product/process technologies were transferred by ISRO. Major technologies transferred during the current year include High Purity Precipitated silica from rice husk ash, in-situ Electropolishing Device, PWM Amplifiers, High Magnification Enlarger, Direct Reception System (Mark-11), an epoxy poly-sulphide adhesive system (EPY-2183), MALAR—a Malayalam-English bilingual word processor software, Pedeclean-A, an industrial hand cleaning cream, a nitrile phenolic adhesive for metal-to-metal bonding application (ISRO-PN-250), a process for high efficiency black chrome coatings and Charge Coupled Device camera. In addition



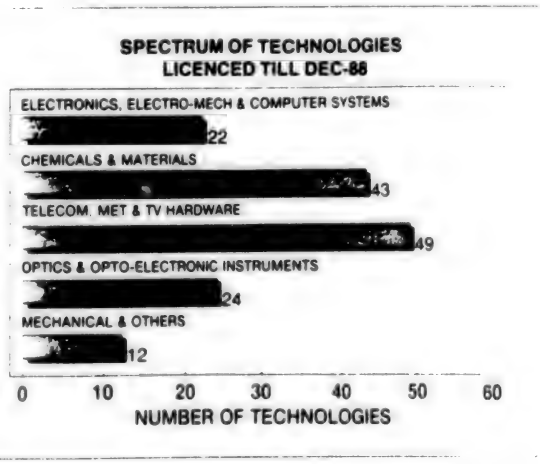
the technology for an adhesive system which was transferred earlier was further licenced to new parties to meet the growing market demand. About 115 products/processes and applications software packages are currently in the pipeline for technology transfer.

The year 1988 witnessed good progress in the utilisation of technologies transferred by ISRO. Among ISRO buy-back items, significant quantities of HTPB fuel binder resin, liquid phenolic resin, high silica cloth and liquid propellants like UDMH and MMH were supplied by Indian industries for the Space Programme. The plant for production of UDMH and MMH at Andhra Sugars Limited, Tanuku, A.P. was formally inaugurated by Honourable Vice President of India on 24 July, 1988. Under the space applications and spin-off categories, ISRO and NRSA licencees significantly increased their production and sale of most of the items including optical reflecting projectors, image analysers, light tables, optical pantographs, dual densitometers, etc. The interactive intelligent image graphics display terminals were delivered during the year. In the INSAT utilisation programme, the data collection, storage and transmission system (DCSTS) manufactured by GCEL and disaster warning receivers manufactured by the Electronics Corporation of India are being used by the India Meteorological Department; and radio networking terminal manufactured by KELTRON is used by All India Radio (AIR). Further, KELTRON commenced production of the second lot of radio networking terminals for AIR. The first set of hardware for news facsimile meteorological data dissemination has been successfully fabricated and the regular commercial production of these are expected to take palce in near future. The state-of-the-art low cost digital image analysis system, ISROVISION, was also successfully developed in industry with ISRO's technology transfer and the first unit was demonstrated to users at different locations in the country. This unique development was completed in a record time by the joint efforts of ISRO and industry where the latter was involved in the development phase itself. The markets for spin-off items have also considerably increased. There has been an overwhelming demand for additional licencing of the polyols, developed by ISRO. The technology transfers to industry for certain items related to rural telegraphy terminals for the Satellite Based Rural Telegraphy Network project, digital speech interpolator, and a process for production of phosphomylated prepolymer from cashewnut shell liquid, etc., are in advanced stages for execution of agreement.

MARKET SURVEYS AND SYSTEM STUDIES

Market survey projects/pre-feasibility reports for a number of items for which technologies have been developed in ISRO were undertaken during the year, including those for hygrophotometer, bonded film lubrication applications, relay parameter tester, spin-off applications for control components, ISROVISION system, video tele-conferencing system, electronics sub-titler, crane control system, drum scanner digitiser, photowrite system, stereo zoom transferoscope, oil fire extinguishant, maleic hydrozides, a wide variety of servo systems related items, thermal sensors, and a versatile integrated check-out, a micro-computer system (VICTOR).

In addition, a number of computer based MIS development and high-tech vendor survey projects were also undertaken. These covered areas such as generation of directory of potential vendors in diverse technology areas for the Space Programme, development of data base for global failure histories of satellites and launch vehicle systems/



components, MIS for monitoring liquid propulsion system test programme, MIS development for sponsored research programmes of ISRO, etc.

PATENTS, COPYRIGHTS, TRADE-MARKS AND DESIGNS

During 1988, the patent applications for which complete specifications were filed include domestic electric shock protector, cooled and uncooled heat flux sensors, process technology for coating/decoating (precise tuning) of diamond like carbon coatings on metal/dielectric/semiconductor substrates electro-optical system for measurement of moisture content, improvements in/or relation to pinhole free rear surface black chrome coatings on glass/quartz or any other equivalent dielectric substrates, a process for chromate coatings on magnesium-lithium alloys, a process for gold plating on magnesium-lithium alloys, a novel method of manufacture of propellant grain, development for deposition of gold on aluminium, etc. Trade marks for 3 items have been applied for.

AWARDS

ISRO won The National Metallurgists Day award for the year 1988 for work on Beryllium metallurgy jointly with BARC. The bilingual word processor package—MALAR—won an appreciation award in the All India Competition for software packages adopted for Indian languages.

PROMOTIONAL ACTIVITIES FOR TECHNOLOGY TRANSFER AND MARKET DEVELOPMENT

A wide spectrum of promotional activities were carried out by ISRO to progress its technology transfer and industry interface activities. These include the generation of a large number of interest exploration notes providing details of technologies developed by ISRO and available for transfer. These were disseminated to a wide range of industries and other high-tech institutions as well as potential users. In addition, announcements were also made in professional journals

and newspapers about the availability of these technologies. Demonstrations were also arranged for various products/processes having potential for technology transfer to industry representatives. These include items like relay parameter tester. A special presentation on the extended C-band communication equipment being developed by ISRO was made to the industry and the users. The presentations highlighted the technology development and transfer potentials as well as business opportunities relating to these equipment. Special demonstration campaigns were also undertaken by ISRO licencees for the newly introduced products like ISROVISION.

A major thrust was continued for promoting markets for remote sensing data utilisation equipment during the year. A special exhibition of remote sensing equipment productionised in industry was organised by the members of the Federation of Remote Sensing Companies of India (FORSCI) and other ISRO licencees, coinciding with the 'National Seminar on IRS-1A Mission and its Application potential'. A large number of users of the remote sensing data in the country attended this seminar. Special presentation was also made by FORSCI to the participants in the seminar on the industry's role in remote sensing.

The industry-interface experts of ISRO & NRSA gave a number of lectures in different industrial and business forums to educate industry and the user community referring the objectives, mechanisms, activities and the past, present and future of Space-Industry partnership.

To prepare the ground for liberal venture capital funding of ISRO's technology licencees in the small and medium scale sectors, ISRO has been actively co-ordinating with designated developmental finance institutions in India such as TDICI and IDBI. The details of the scheme have been disseminated to scientists and professionals within ISRO as well as to the licencees of ISRO technologies. Some licencees have been provided assistance through venture capital funding scheme for productionising and commercialising the technologies developed in ISRO.

ISRO has also directly undertaken the international market promotion of the wide range of ISRO & NRSA developed low-cost remote sensing utilisation equipment produced by various industries in India. This campaign was directed mainly towards other developing countries in Asia, Africa and Latin America. Information on this was also disseminated to a wide body of potential users of the systems abroad and for publication in various international directories and newsletters reaching the target population. Export promotion agencies in India have also been informed of the technologies available for export from the Space Programme. A special effort was also mounted to encourage the data reception and data procurement from the Indian Remote Sensing Satellite in other countries. Information on the specific equipment to be established for such data reception and the Indian capabilities to support the supply and establishment of these equipment was provided to potential user agencies in other countries. Special exhibitions, literature dissemination and discussion sessions were arranged for the benefit of many international participants at the 39th Congress of International Astronautical Federation held at Bangalore during October, 1988.

ISRO TECHNOLOGICAL CONSULTANCY SCHEME

Under this scheme ISRO has been providing expertise to Indian industries and other R&D institutions in a wide range of disciplines.

Since 1982, over 80 technological consultancy projects have been undertaken by ISRO for various industrial and technological institutions. During 1988, eight new assignments were undertaken. These included consultancy/guidance for commissioning of the hydrazine hydrate plant, development of NOx analyser, development of a power protection system, and a wide range of video programmes related to the developmental education and communications.

CONTRIBUTIONS FROM INDUSTRIES

Significant contributions from Indian industries were realised during the year resulting in considerable progress of the on-going space projects like PSLV & INSAT-II Test Spacecraft. Specialised production lines created in Indian industry were successfully geared up to meet the higher throughput requirements for supply of rocket hardware and components with increased complexity for PSLV project. 15 segments of rocket motor case hardware in maraging steel of 2.8 m dia, 4 motors for the strap-on booster stage, and all the 7 end domes were successfully fabricated and delivered from industries for PSLV. In addition, a large propellant casting mandrel as well as handling rings for the first stage motor were also delivered. Subsequent to the successful establishment of specialised facilities in the Aerospace division of HAL, the production of light alloy structures for PSLV went on and 15% of the light alloy structure requirements have already been fabricated and delivered to the project. A large number of precision manufacturing industries in the country were utilised to fabricate and supply components for light alloy structures. Such an orchestration of precision engineering industries in the country led by HAL for realising complex systems is an example of time and cost effective approach evolved by the PSLV project. In its effort to further farm out the in-house operations involving multiple operations and higher level of complexities to industry, the space programme was successful in developing an industrial partner for undertaking the complete set of operations leading to the provision of insulated rubber lining for the solid stage motors of PSLV. Similarly extensive efforts made for the development of production capabilities for rocket propellants in industry involving both solid and

liquid propellants yielded significant results in terms of regular supplies of propellant fuels and binders like UDMH, MMH, Ammonium perchlorate, HTPB and N_2O_4. The specialised mixing equipment for large scale processing of propellants have been developed using extensive fabrication support from industry. The capabilities developed in Indian industry to supply special items like high-silica cloth and liquid phenolic resin are continuing to service the Space Programme's needs. Intensive efforts are made for development of high-tech. vendors for production of specialised items like carbon cloth and composite nozzle systems for future launch vehicles. These efforts are expected to fructify in the next couple of years in establishing industrial lines involving advanced processing techniques for servicing the future space programmes. Indian industry provided crucial support in developing specialised systems for the launch vehicles in the area of precision inertial sensors/systems for navigation and guidance.

The Space Electronics Division of the Bharat Electronics Ltd. (BEL) continued to provide support for the Space Programme for the production of avionics systems used in the launch vehicles/ sounding rockets and ground systems used in the tracking stations for supporting various missions like IRS-1A and ASLV. Wide ranging developments in materials/fabrication processes for the launch vehicle programmes undertaken by the Space Programme in participation with various industries and national institutions have resulted in savings not only in terms of the time for effective absorption of technology at the delivery end, but also in costs due to shared efforts/infrastructure of many industries/institutions. The major developments that have served the PSLV and other projects include the developments/ production of maraging steel and the associated fabrication processes, specialised Al. alloy rings and a wide range of specialised forgings.

The liquid propulsion stages which are being developed for the first time in the country for PSLV have received significant support from industries. The VIKAS engine elements for PSLV are realised in a dozen industries. The liquid upper stage elements are realised in five industries. The components used in the control systems of ASLV & PSLV and the control power plant elements were successfully realised in the industry. The whole range of light weight structural elements such as aluminium tankages, inter-stage structures, thrust frame and titanium alloy tankages, have been fabricated in the industry. Encouraged by the performance of various components developed in Indian industries for the VIKAS liquid engine which will be used in PSLV & GSLV programmes, efforts are mounted to develop high-tech. vendors in industry who would take up the manufacture of the entire engine or its major sub-systems. The development of a few specialised manufacturers for this major system would not only result in scaling up the level of participation of industry in the Space Programme but also ensure a sustaining base for supply of these engines in large numbers as required by the future programmes. The development of liquid propulsion engine in the country has involved use of many new and advanced materials and alloys along with the development of fabrication processes associated with them. A special programme is mounted for producing these special materials utilising the infrastructure available in industries and other research institutions in the country.

In support of the advanced R&D programmes initiated for the development of cryogenic engine, various industries and research institutions are being involved extensively. The range of activities

in which active participation from industries/institutions is sought include production of high purity oxygen free high conductivity copper, development of specialised titanium alloys for storage of cryogenic fuels, production of specialised insulation systems, adhesives and sealants, fabrication of various elements for scaled-down version of cryogenic engine, thrust chamber, cryo-valves, plumbing systems, cryogenic heat exchangers, transportation/storage systems, and sensors, all of which involve specialised manufacturing processes.

For the sounding rocket programme, Indian industries supplied the full range of hardware. Indian industries have supported supply of hardware for 100 sounding rockets of RH-200 type and 70 rockets of RH-125 type. The various avionic systems used in these rockets involving telemetry, telecommand and communication systems have been produced and supplied by the Space Electronics Division of BEL.

For the ISRO's satellite programmes, Indian industry has contributed significantly in terms of development and supply of satellite structures and high reliability electronic circuits apart from a wide range of ground test and handling systems. For the augmentation of the satellite and launch vehicle tracking network, the Indian industry played substantial role in the development and supply of servo systems, large antenna structures and instrumentation systems. The reflectors and very precision mounts involved in the establishment of Precision Coherent Monopulse C-Band Radar (PCMC) have been under fabrication in industries. The other major systems which have been under development in industry in a consortia mode pertain to the PSLV Mobile Service Tower and Large Space Simulation Chamber. Considerable progress has been achieved in the fabrication of the Mobile Service Tower and the associated power and environmental control systems during the year and the facility is expected to be commissioned by the first half of 1989.

VENDOR DEVELOPMENT EFFORTS FOR INDIGENISATION OF ELECTRONICS

The efforts for development of vendors for indigenous productionisation of electronic parts have continued. A joint study team involving ISRO and BEL have examined and identified a number of hi-rel parts that could be indigenised. This team has also studied the various aspects related to the programme of indigenisation which is now under consideration for appropriate implementation. The type of parts covered by the above exercise included a variety of diodes, transistors, linear ICs and digital ICs. Efforts for qualification of indigenously produced components for space use have been made in collaboration with a number of indigenous manufacturers, for Zener diodes, Signal transistors, Switching diodes, Power transistors and Tantalum capacitors. ISRO also has jointly funded with other user departments for the development and qualification of radiation hardened VLSI circuits in industry. The efforts to develop vendors for supply of Space qualified hybrid micro circuits and multilayer boards have continued. Through a special development and supply contract with HAL, Hyderabad, metallisation and circuit engineering of Microwave Integrated Circuits for solid state power amplifiers used in satellite communication has been taken up. Specific thrust in promoting ISRO-Industry partnership is given by evolving corporate level dialogue with ITI for productionisation of a number of communication related systems. This programme envisages joint efforts for technology development and use of infrastructure in both ISRO and ITI as well as qualification of certain facilities in ITI for MICs, ASICs, LSI/VLSI, HMC, MLB, etc., for Space use.

These components have been assembled successfully and the beryllium gyros have undergone acceptance tests at VSSC.

Utilising this unique infrastructure, a programme on indigenous development of beryllium mirrors for inertia critical spacecraft optical applications has been undertaken. Small size beryllium VHP blocks have been subjected to critical processing stages like precision machining including mass relieving, electroless nickel coating, lapping and polishing. The R&D efforts are expected to help standardisation of the processing methods when large size mirrors are taken up for fabrication to meet needs of future Space projects. These efforts have active participation by national laboratories like CECRI, Karaikudi and NAL, Bangalore, and Indian industries. □

BERYLLIUM FACILITIES

The Beryllium Pilot Plant (BPP) at Vashi, a joint project of BARC, ISRO and DOE has demonstrated full capability to produce vacuum hot-pressed (VHP) instrument grade beryllium blocks to the required standard specifications after instituting tight quality control measures. The Beryllium Machining Facility (BMF) set up by ISRO has developed the necessary machining methods and has been producing high precision beryllium components for inertial grade gyro applications.

Glossary

ABR: Air Breathing Rocket

ACCT: Ancillary Computer Compatible Tapes

ACSL: Advanced Continuous Simulation Language

ADCOS: Advisory Committee for Space Sciences, constituted by ISRO

ADRSN: ASLV Down Range Station

AES: Ahmedabad Earth Station

AOCS: Altitude & Orbit Control System

AOTV: Aero-assisted Orbital Transfer Vehicle

APC-REX: Autonomous Payload Control Rocket Experiment, a joint ISRO-DFVLR experiment

APC-STEX: Autonomous Payload Control Satellite Experiment, a joint experiment planned by ISRO and DFVLR.

API: Advance Publication Information

ASIC: Application Specific Integrated Circuit

ASLV: Augmented Satellite Launch Vehicle. An augmented version of the SLV-3 with strap-on boosters and capable of launching 150 kg class satellites into near-earth orbits.

ASTROPHYSICS: The study of physical properties such as luminosity, size, mass, density, temperature, and composition of celestial bodies.

ATF: Acoustic Test Facility

AVP: Application Validation Projects

BARC: Bhabha Atomic Research Centre

BEL: Bharat Electronics Limited

BES: Bureau of Economic Statistics

BFL: Bonded Film Lubrication

BHEL: Bharat Heavy Electricals Limited

BLP: Boundary Layer Physics

BMF: Beryllium Machining Facility

BOL: Beginning of Life

BPP: Beryllium Pilot Plant

BRLS: Balasore Rocket Launching Station

BSS: Broadcast Satellite Service

CAD: Computer Aided Design

C-BAND: Frequency band between 4.0 and 8.0 GHz

CCAP: Cable Coupling Analysis Programme

CCD: Charge Coupled Device

CCSDS: Consultative Committee for Space Data Systems

CCT: Computer Compatible Tape

CCTV: Closed Circuit Television

CDR: Critical Design Review

CECRI: Central Electro-Chemical Research Institute, Karaikudi

CESS: Centre of Earth and Space Sciences

CFRP: Carbon Fibre Reinforced Plastic

CG: Centre of Gravity

CIG: Computer and Information Group

CIIL: Central Institute of Indian Languages

CLASS: Computer Literacy & Studies in School

CMFRI: Central Marine Fisheries Research Institute

CMM: Co-ordinate Measuring Machine

CMO: Central Management Office

CNC: Computer-aided numerically controlled machine used for precision machining purposes

CNES: Centre National d'Etudes Spatiales (French National Space Research Agency)

CNS: Communications, Navigation & Surveillance

COSMIC RAYS: Extremely high-energy sub-atomic particles which traverse the solar system

COSPAR: Committee on Space Research of the International Council of Scientific Unions (ICSU) of which the Indian National Committee for Space Research (INCOSPAR) is a component

COSPAS: Search & Rescue Satellite System of the USSR

CPCS: Comunication Payload Check-out System

CPU: Central Processing Unit

CSD: Communication Systems Division

CSIO: Central Scientific Instruments Organisation

CSIR: Council of Scientific & Industrial Research

CWC: Central Water Commission

DAE: Department of Atomic Energy

DCE: Data Communication Equipment

DCP: Data Collection Platform

DCSTS: Data Collection Storage and Transmission System

DECU: Development & Educational Communication Unit at Ahmedabad

DEMUX: Demultiplexer

DES: Delhi Earth Station

DFVLR: Deutsche Forschungs und Versuchsanstalt fur Luft und Raumfahrt (German Aerospace Research Establishment)

DGCA: Directorate General of Civil Aviation

DOE: Department of Electronics

DOEn: Department of Environment

DOT: Department of Telecommunications

DPS: Data Processing Systems

DRS: Direct Reception Sets for TV reception directly from the satellite under the INSAT System

DRT: Data Relay Transponder

DSI: Digital Speech Interpolation

DST: Department of Science & Technology

DTG: Dry Tuned Gyro

DTM: Digital Terrain Modelling

DWR: Disaster Warning Receivers

DWS: Disaster Warning System

ECIL: Electronics Corporation of India Limited

ECT: Emergency Communication Terminal

EFF: Electronic Fabrication Facility

EGC: Engine Gimbal Control

EGSE: Electrical Ground Support Equipment

ELB: Emergency Locator Beacons

EMI: Electromagnetic Interference

EMRC: Educational Media Research Centre

EOL: End of Life

EPDM: Ethylene Propylene Dimer compound used in rocket motor insulation and control system bladder applications

EPIRB: Emergency Position Indicating Radio Beacon

ERS-I: European Remote Sensing Satellite-I

ESA: European Space Agency

ESF: Earth Simulator Facility

ESTEC: European Space Research & Technology Centre at Noordwijk, The Netherlands

ETM: Electrical Thermal Model

EWC: Equatorial Wave Campaign

FAC: Failure Analysis Committee

FEAST: A general purpose software for Finite Element Analysis of Structures

FMECA: Failure Mode Effects and Criticality Analysis

FMO: Frequency Management Office

FORSCI: Federation of Remote Sensing Companies of India

FOV: Field of View

FRP: Fibre-Reinforced Plastics. High Strength, light weight composite material comprising high strength fibres of materials such as glass, boron and carbon graphite in a matrix of plastic.

FRR: Flight Readiness Review

FSAM: Flexible Solar Array Mechanism

FSS: Fixed Satellite Services

FSDU: Frame Synchronisation and Decommutation Unit

GCEL: Gujarat Communications Electronics Limited

GCP: Ground Control Point

GEO-STATIONARY SATELLITE: A satellite which appears stationary relative to any point on the Earth. This is achieved by synchronising the revolution of the satellite around the Earth with the speed of Earth's rotation about its own axis by placing the satellite into an equatorial orbit of about 36,000 km above the Earth. Geo-stationary satellites are used for communication as their antennae can be kept facing a particular fixed region on the Earth. The APPLE and INSAT satellites are geo-stationary.

GG: Gas Generator

GIS : Geographic Information System

GPS: Global Positioning System

GRB: Gama Ray Burst

GSLV: Geo-synchronous Satellite Launch Vehicle to be developed by ISRO for launching the indigenous second generation INSAT-II satellites

GTO: Geo-synchronous Transfer Orbit

GTR: Ground Truth Radiometers

GTS: Global Telecommunication System

HAL: Hindustan Aeronautics Limited

HAT: High Altitude Test

HDDTR: High Density Digital Tape Recorder

HMC: Thick Film Hybrid Micro Circuits

HME: High Magnification Enlarger

HPA: High Power Amplifier

HPR: Helium Pressure Regulator

HTPB: Hydroxyl Terminated Polybutadiene

ICAO: International Civil Aviation Organisation

ICC: INSAT Co-ordination Committee

IEEE: Institution of Electrical and Electronics Engineers

IFRB: International Frequency Registration Board

IGS: Inertial Guidance System

IIA: Indian Institute of Astrophysics

IIGDT: Interactive Intelligent Image Graphics Display Terminal

IIRS: Indian Institute of Remote Sensing at Dehra Dun. Formerly known as Indian Photo Interpretation Institute (IPI) and set up in 1966 under the Survey of India, it is now a part of NRSA

IMAP: Indian Middle Atmosphere Programme. A Scientific research programme to investigate the physical and chemical phenomena and processes taking place in the atmosphere between 10 and 100 km. Besides ISRO and PRL, a number of other national agencies and institutions are participating in IMAP.

IMD: India Mateorological Department

IMDAS: Interactive Multispectral Data Analysis System

IMS: Information Management System

INMARSAT: International Maritime Satellite Organisation

INS: Inertial Navigation Sensors

INSAT: Indian National Satellite. INSAT is a multipurpose satellite in the geo-stationary orbit for domestic long distance telephony, meteorological earth observation, disaster warning, direct TV broadcasting and programme distribution.

INSAT-II TS: INSAT-II Test Spacecraft. A test version of the indigenous second generation INSAT (INSAT-II) satellites under development

INSTEF: Integrated Structural Test Facility at VSSC

INTELSAT: International Telecommunications Satellite Organisation

IONOSPHERE: The region of the earth's upper atmosphere where part of the gases are ionised. The ionosphere 'reflects' radio waves facilitating long-distance communication.

IOR: Indian Ocean Region

IPS: Interplanetary Scintillations

IRAS: Infrared Astronomy Satellite

IREX: ISRO Range Complex comprising the satellite launching facility at SHAR and the sounding rocket ranges at Sriharikota, Thumba and Balasore

IRS: Indian Remote Sensing Satellite. The first in the series, IRS-1A, was launched into a 904 km polar Sun-synchronous orbit.

IRU: Inertial Reference Unit

ISAC: ISRO Satellite Centre, Bangalore

ISP: Interplanetary Scintillations Project

ISTRAC: ISRO Telemetry, Tracking and Command Network. ISTRAC manages the ground support network for tracking, data acquisition and spacecraft control operations for India's Space projects

ITU: International Telecommunications Union

IUP: IRS Utilisation Programme

IXAS: Indian X-ray Astronomy Satellite

JEP: Joint Experiment Programme

KCP: Kheda Communications Project

LAM: Liquid Apogee Motor

LANDSAT: A series of Sun-synchronous Satellites of NASA orbiting at altitudes of around 800 km

in polar orbits, for remote sensing of Earth resources. India is using LANDSAT imageries for resources survey. A station for receiving data from LANDSAT is operated by NRSA near Hyderabad.

L-BAND: 1 to 2 GHz frequency range

LCT: Low Cost Terminal

LEO: Low Earth Orbit

LFC: Large Focal Length Camera

LINAC: Linear Accelerator used for the inspection of solid propellant grains

LISS: Linear Imaging Self Scanning Camera, used on-board the Indian Remote Sensing Satellite, IRS-1A

LMC: Large Megallenic Cloud

LMSS: Land Mobile Satellite Service

LNA: Low Noise Amplifier

LOX: Liquid Oxygen

LPSC: Liquid Propulsion Systems Centre

LPTF: Liquid Propulsion Test Facilities at Mahendragiri, Tamil Nadu, is a part of LPSC

LRV: Lifting Re-entry Vehicle

LSI: Large Scale Integrated Circuit

LSSC: Large Space Simulation Chamber

LUS: Liquid Upper Stage

LUT: Local User Terminal

MALAR: A bilingual word processor package for English and Malayalam

MBPS: Mega Bits Per Second

MCC: Mission Control Centre

MCF: Master Control Facility for INSAT-I at Hassan, Karnataka

MDC: McDonnel Douglas Corporation

MDUC: Meteorological Data Utilisation Centre, New Delhi. The primary Centre for collection and processing of satellite meteorological data in the country.

MEOSS: Monocular Electro-Optical Stereo Scanner, the remote sensing payload of DFVLR for the SROSS-2 mission

MIC: Thin film Microwave Integrated Circuits

MICROARTS: Microprocessor aid to real-time systems, a general purpose real-time check-out system

MIDAS: Multi-spectral Interactive Data Analysis System

MIS: Management Information System

MGSE: Mechanical Ground Support Equipment

MLB: Multi Layer printed circuit Board

MMH: Mono-Methyl Hydrazine, a liquid propellant

MoS_2: Molybdenum-di-Sulphide

MOU: Memorandum of Understanding

MRC: Malaria Research Centre

MRSP: Microwave Remote Sensing Programme

MSS: Mobile Service Structure

MSS: Multi Spectral Scanner

MST: Mobile Service Tower

MST RADAR: Mesosphere, Stratosphere and Troposphere Radar

MUX: Multiplexer

MWA: Momentum Wheel Assembly

NAL: National Aeronautical Laboratory, Bangalore

NASA: National Aeronautics & Space Administration of USA

NASCAP: NASA Spacecraft Charging Analysis Programme

NASDA: National Aeronautics & Space Development Agency of Japan

NDC: NRSA Data Centre

NDT: Non-Destructive Testing

NFDMC: National Forest Data Management Centre

NGCP: Navigation, Guidance and Control Processor

NNRIS: National Natural Resources Information System

NNRMS: National Natural Resources Management System. The National System of Central and State user agencies for the utilisation of remote sensing data and information from conventional means for efficient management of natural resources.

NOAA: National Oceanographic & Atmospheric Administration of USA

NOCIL: National Organic Chemical Industries Limited

NRIS: Natural Resources Information System

NRSA: National Remote Sensing Agency, Hyderabad

OLR: Outgoing Longwave Radiation

ONGC: Oil & Natural Gas Commission

ORP: Optical Reflecting Projector

OSR: Optical Solar Reflector

PBAN: Polybutadiene Acrylic Acid Acrylo Nitrile, a rocket propellant

PC: Personal Computer

PCB: Printed Circuit Board

PCMC: Precision Coherent Monopulse C-band Radar

PCTF: Passive Cooler Test Facility

PDR: Preliminary Design Review

PDS: Page Display System

PEPS: Preliminary Evaluation Programme for SPOT, the French Satellite

PFA: Post Flight Analysis

PLASMA: An electrically conductive gas consisting of neutral particles, ionised particles and free electrons, but which, as a whole, is electrically neutral

POD: Preliminary Orbit Determination

POLAR ORBIT: Orbit for an artificial satellite crossing the north and south polar regions. Such an orbit permits the satellite to periodically scan all points on the Earth's surface. This is particularly useful in remote sensing applications. IRS satellites will be placed in polar orbits.

PRIMAT: A Primary Multiplex Equipment used for voice encoding

PRL: Physical Research Laboratory, Ahmedabad

PRODAT: Data only communications terminal used in the PROSAT programme. PROSAT is the communications programme of ESA for the development of mobile satellite communication system

PSLV: Polar Satellite Launch Vehicle. An ISRO launch vehicle under development to launch 1,000 kg class remote sensing satellites in polar Sun-synchronous orbit of 900 km altitude

PTS: Principal Test Stand for testing liquid propellant engines

QA: Quality Assurance

QC: Quality Control

QLDA: Quick Look Data Analysis

QPSK: Quadrature Phase Shift Keying

RCC: Rescue Co-ordination Centre

RCS: Reaction Control System

RDSS: Radio Determination Satellite Service

REARS: Redundant Attitude Reference System

REMOTE SENSING: Remote Sensing is the process of detecting the nature and properties of an object from a remote position. In the Space Technology context, it concerns the survey of natural and renewable earth resources and the environment using air-borne and space-borne sensors.

REPIN: An insulation material of rubber developed at VSSC

REPLACE: ISRO's Reinforced Plastics Centre at Vattiyoorkavu, Trivandrum

RESINS: Redundant Strap-down Inertial Navigation System

RESPOND: Research sponsored by ISRO. An ISRO scheme to initiate and support research in activities of interest to space science, technology and applications in academia and research institutions in India.

RFNA: Red Fuming Nitric Acid, a liquid oxidiser

RH-200: Two-stage sounding rocket with a 200 mm diameter booster used mainly for meteorological applications

RH-300: Single-stage sounding rocket of 300 mm diameter

RH-560: Presently India's largest sounding rocket, with two stages. The first stage consists of a 560 mm diameter rocket and the second an RH-300 or its equivalent.

RIG: Rate Integrating Gyro

RJE: Remote Job Entry

RN: Radio Networking

R&QA: Reliability & Quality Assurance

RRSSC: Regional Remote Sensing Service Centre

RSAM: Remote Sensing Applications Mission

RSP: Resources Survey Projects

RSR: Rohini Sounding Rocket

RWA: Reaction Wheel Assembly

SABREX: A 90 GHz satellite-borne Radiometer Experiment being planned jointly by ISRO and DFVLR

SAC: Space Applications Centre, Ahmedabad

SADA: Solar Array Drive Assembly

SAMEER: Society for Applied Microwave Electronic Engineering Research, Bombay

SAR: Synthetic Aperture Radar

SAS&R: Satellite-Aided Search & Rescue

SAW: Surface Acoustic Wave

S-Band 2.0 GHz: The 2.0-4.0 GHz frequency range. The frequency around 2.0 GHz has minimum galactic and atmospheric noise. As a result, most telemetry and deep space communications use this band.

SBRTN: Satellite-Based Rural Telegraph Network

SBSA: Swedish Board for Space Activities

SCC: Spacecraft Control Centre

SCHCNE: USSR State Committee on Hydrometeorology and Control of Natural Environment

SCOF: SHAR Computer Facility

SCOT: Small Communication Terminal

SCOUT: Serial Check-out Unit

SDUC: Secondary Data Utilisation Centres located in different parts of the country for collection and processing of satellite meteorological data

SED: Space Electronics Division of BEL

SFCG: International Space Frequency Co-ordination Group

SHAR: ISRO's Launch Centre at Sriharikota, Andhra Pradesh

SHARES: A programme for Sharing of Experience in Space

SIF: Satellite Integration Facility

SIP: Simulated Input Profile

SIR-B: Shuttle Imaging Radar-B

SITVC: Secondary Injection Thrust Vector Control System

SLAR: Side-Looking Air-borne Radar

SLV-3: A four-stage solid propellant Satellite Launch Vehicle of ISRO. The successful second developmental flight of April 18, 1983, which orbited the RS-D-2 satellite, marked the culmination of this project. The first successful flight took place in 1980.

SM: Structural Model

SMD: Surface Mounted Devices

SM&ETM: Structural Model and Electrical Thermal Model

SML: Shape Memory Alloys

SOE: Sequence of Events

SOUNDING ROCKET: A rocket for the exploration of the upper atmosphere. These rockets are normally launched almost vertically to heights ranging from tens to a few hundreds of kilometres. The Rohini (RH) series of rockets made by ISRO are sounding rockets.

SPINS: Stabilised Platform Inertial Navigation System for launch vehicle guidance

SPOT: The French remote sensing satellite. The ground station of NRSA receives data from SPOT for remote sensing application studies.

SPROB: Solid Propellant Space Booster at SHAR

SROSS: Stretched Rohini Satellite Series, 3-axis as well as spin-stabilised spacecraft of 150 kg class for launch by ASLV

SRRT: S-Band Range and Range Rate Transponder

SSMA: Spread Spectrum Multiple Access

SSPA: Solid State Power Amplifier

SST: Sea-surface Temperature

STARS: Satellite Tracking & Ranging Station, Kavalur

STC: Space Technology Cell

STEX: Static Test & Evaluation Complex at SHAR

STFSDS: Standard Time and Frequency Signal Dissemination Service

STS: Space Transportation System of NASA

TAG: Technical Advisory Group

TASI: Time Assigned Speech Interpolation

TCXO: Temperature Compensated Crystal Oscillator

TDMA: Time Division Multiple Access

TERLS: Thumba Equatorial Rocket Launching Station

TIFR: Tata Institute of Fundamental Research, Bombay

TM: Thematic Mapper

TRACT: Transportable Remote Area Communication Terminal

TTC: Telemetry, Tracking & Command

TVC: Thrust Vector Control System

TVRO: Television, Receive Only

TWTA: Travelling Wave Tube Amplifier

UDMH: Unsymmetrical Dimethyl Hydrazine, a liquid fuel for rockets

UGC: University Grants Commission

USO: Udaipur Solar Observatory

VHF: Very High Frequency (between 30 and 300 MHz)

VHRR: Very High Resolution Radiometer, for producing high resolution pictures of meteorological phenomena. The INSAT-IB spacecraft carries a VHRR

VIB: Vehicle Integration Building

VICTOR: Versatile Integrated Check-out Microcomputer System

VLPRT: Very Low Power Radio Transmitter

VLSI: Very Large-Scale Integrated Circuit

VSAT: Very Small Aperture Terminal

VSSC: Vikram Sarabhai Space Centre, Trivandrum

WARC: World Administrative Radio Conference

WMO: World Meteorological Organisation

X-Band: The nominal frequency range of 8 to 12 GHz. □

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